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HYPOPARIA AND OPISTHOPARIA FROM THE ST. CLAIR LIMESTONE, ARKANSAS

NORMAN L. THOMAS[1]

Received January 14, 1929; published April 24, 1929

I. HYPOPARIA

Ampyx Dalman, 1837

"Cephalic shield somewhat trigonal; glabella large, prominent, narrow behind, and projecting upward and forward anteriorly; cheeks flattened, posterior angles produced; no eyes or facial sutures; thoracic segments five or six, flattened, sides straight, divided by a diagonal pleural groove; pygidium subtrigonal, nearly as large as the cephalic shield; one anterior segmental furrow; axis faintly marked with transverse furrows."[2]

Ampyx niagarensis Van Ingen, 1901

Fig. 1

CEPHALON sub-triangular, with ovaliform glabella protruding in front and bearing a long anterior cylindrical spine, posterior margin nearly straight. Glabella ovaliform, flattened on under surface but strongly convex on the top and sides, protruding anteriorly about half its length beyond the cheeks, occipital furrow at posterior end; glabella pointed at the anterior apex where a slender cylindrical spine extends straight forward. Axial furrows rounded, well marked, almost straight extending obliquely backward and inward to the occipital furrow. A pair of pits or oval depressions on either side of the glabella close to the dorsal and occipital furrows are the only suggestions of lateral glabellar furrows. Occipital furrow rounded, extending straight across the posterior end of the glabella. Occipital ring slightly

[1] *Published with permission of Chief Geologist of Pure Oil Company.*

[2] Miller, S. A. N. A. Geol. & Paleo. 528 (1889).

arched, convex, narrow and indistinct. Cheeks triangular, convex, greatest convexity on the outer portion where anterior and lateral slopes are steep, rather depressed in inner posterior corners.

Measurements of two cephalons

	mm.	mm.
Length of cephalon (exclusive of spine)	2.5	1.8
Maximum width of cephalon	3.0	2.0
Maximum width of glabella	1.4	1.0
Width of glabella along occipital furrow	0.4	0.3

Remarks.—This species differs from *Ampyx rouaulti* Barrande, in having a narrower central glabellar lobe produced farther anteriorly, and from *Ampyx portlocki* Barrande, in the same respects and also in having the pair of depressions on the outer flanks of glabella near the occipital and dorsal furrows.[3]

Van Ingen makes the following comments: "This species closely resembles *Ampyx parvulus* Forbes,—from the greenish gray mudstone of the lower Ludlow rocks, Vinnal Hill, Ludlow, England; differing from it in the longer and narrower glabella and less tumid cheeks. *Ampyx parvulus* Forbes is listed by Etheridge as from the Caradoc-Bala, and the Wenlock shale.

Ampyx niagarensis is the first *Ampyx* to be recorded from the Siluric horizons of North America. The genus is with few exceptions confined to the rocks of the Ordovician, in the upper horizons of which system the majority of the European species occur. In North America the six known species are all from the Lower Ordovician, none of the species having been found from a horizon higher than the Trenton limestone. From all the published figures of the American species *Ampyx niagarensis* differs in the anterior portion of the glabella being much more produced over the limbus."[4]

II. OPISTHOPARIA

Bumastus Murchison

Opisthoparia with large, convex cephalon and pygidium in form of shield. Axial lobe of thorax equal to more than half the

[3] Barrande, J. Systeme Silurien Boheme 52 (1846).
[4] Van Ingen. School Mines Quart. 23: 53, 54 (1901).

width of the specimen, thorax with eight to ten segments. Pygidium without ribs, usually with concave border on the pygidium and frequently on both the cephalon and the pygidium; axial lobe short or absent; eyes large. In Zittel's *Text book of Paleontology* Raymond differentiates between *Illaenus* and *Bumastus* by saying that the former is an *Illaenidae* with "Axial lobe about one-third the total width," and the latter an *Illaenidae* with "Axial lobe very wide; cephalon and pygidium smooth."

Bumastus ioxus Hall

Figs. 2, 3, 4, 5

Cephalon sub-ovate in outline, large specimens moderately convex, small specimens considerably more convex, sub-truncate in front between the anterior ends of the facial sutures. (This last character is not marked in itself unless compared with other species.) Dorsal furrows broad, indistinct except for a pair of small sub-lunar depressions between the eyes, extending from the anterior margin forward and becoming obsolete opposite the anterior extremities of the eyes. Eye lobes sloping convexly, laterally and posteriorly. Eyes large, situated posteriorly. Facial sutures extend from anterior margin in a sigmoidal curve to the eyes, curve around the eye lobes, and drop to the adjacent posterior margin. Minimum median width between the facial sutures equal to, or less, than the length of the cephalon. Free cheeks large, longer than wide, the distance from the eye to the frontal margin a little more than half the distance from the eye to the lateral margin, with depressed semi-circular furrow below the eye and above which is a conspicuous rounded ridge, parallel to the eye. Genal angles rounded. PYGIDIUM sub-triangular, convex, greatest convexity along the lateral margins but rather flat in the middle near the anterior margin. Anterior margin in outline made up of three roughly straight sub-equal sectors, viz.: the middle one at right angles to the axis of the trilobite, and one on either side extending diagonally more outward than backward. Lateral and posterior margins semi-circular with concave border. Axial furrows absent.

Measurements of two cephalons and two pygidia

	mm.	mm.
Length of cephalon	30	15
Maximum width between facial sutures	34	17
Width of cephalon		20
Length of pygidium	33	10
Width of pygidium	43	13

Remarks.—If *Bumastus ioxus* is characterized by its large size, two species are described as one in this paper. The cephalons of the large forms are less convex and slightly less rounded in posterior outline than the smaller. The small ones (Fig. 4), however, closely simulate the large and while there is not a complete series between the two it seems to the writer that the differences may be due to differences in maturity. A few intermediate forms (Fig. 5) lend to this theory, which however is not fully established, there being a large number of small forms and then quite a gap with only a few intermediate ones and again a great group of large specimens. This of course may be due to faulty collecting.

This species differs from *Bumastus clairensis* in having shorter, less distinct axial furrows, sigmoidal anterior facial sutures, and in being slightly less rounded in posterior outline. It differs from *Bumastus graftonensis* in having thinner free cheeks which are "rolled under" and also in having a less rounded genal angle. The length of the cephalon is also greater.

Bumastus clairensis novum

Fig. 6

CEPHALON moderate in length, quite convex, the dorsal border rather truncate or only slightly curved. Minimum width between the facial sutures about equal to the maximum length, greatest convexity a little posterior to the middle. Posterior border of the glabella curved outward quite convexly. Dorsal furrows very broad and rounded, beginning at the posterior margin and extending forward in concave curve, converging slightly, and then as the greatest convexity of the cephalon is crossed continuing more faintly in the same concave curve, and then diverging. As they fade away they point toward the

lateral facial sutures about midway between the eyes and the anterior margin. Eyes large, situated posteriorly; eye lobes convex, slightly arched transversely, protruding laterally beyond the glabella and the other parts of the fixed cheeks. Facial sutures extending almost straight back from anterior margin circle palpebral lobes and reach adjacent posterior margin. Fixed cheeks indefinitely defined by the axial furrows. Free cheeks and eyes unknown. THORAX and PYGIDIUM not identified.

Measurements of two cephalons

	mm.	*mm.*
Length of cephalon	21	22
Maximum width between fixed cheeks	23	24
Minimum width between facial sutures	20	20

Remarks.—This species is characterized by the rather elongate, broad, curved, well marked axial furrows, by the maximum convexity posterior to the middle of the cephalon, by the backward curved extension of the glabella, and by the rather truncated anterior margin, and the straight, almost parallel anterior parts of the facial sutures. It resembles *Bumastus armatus*[5] but differs in the straight parallel anterior facial sutures and the less rounded frontal margin.

It differs from *Bumastus ioxus* in the straight parallel anterior facial sutures and the rather elongate curved, well-rounded axial furrows.

Bumastus graftonensis Meek & Worthen

Fig. 7

CEPHALON short, moderately convex, hemi-elliptical in outline, greatest width across the cranium through the eyes, the dorsal surface rounded under to the ventral surface on the lateral and anterior borders. Minimum width between facial sutures as great or greater than the maximum length. Dorsal furrows indistinct, starting as very obscure depressions from the offsets on the posterior margin and extending forward, converging slightly and ending in a pair of indistinct sub-lunar depressions opposite the eyes, these depressions disappearing completely anteriorly. Eyes large, situated posteriorly, eye lobes sloping

[5] Weller, Stuart. Chicago Acad. Sc. IV, pt. II (1907).

gently from the dorsal furrows. Each facial suture extends from the frontal margin in a gentle sigmoidal curve to the eyes, and from the back of the eye in a short outward and backward sweeping curve to the posterior margin. The free cheeks are depressed beneath the eyes, horizontal for half their width but rolling downward and under. THORAX and PYGIDIUM not identified.

Measurements of two cephalons

	mm.	mm.
Length of cephalon	20	14
Maximum width between facial sutures	23	17

Remarks.—This species is distinguished from *Bumastus ioxus*, which it resembles quite closely, by its shortness, and by the "rolling under" of the free cheeks and of the frontal margin, and the lack of the truncated appearance to the anterior margin.

Illaenoides Weller

Complete body sub-elliptical in outline, the trilobation well marked except upon the pygidium. Cephalon strongly convex, smooth, having well marked dorsal furrows which give the head a distinctly trilobate appearance. Eyes small. The facial suture extends from the anterior border in a very gentle sigmoidal curve to the eye and from there extends in a gentle concave curve backward and slightly outward to the posterior border of the head. Free cheeks triangular. Thorax with nine or ten broad, short, distinctly trilobate segments. PYGIDIUM semi-elliptical or equilateral-sub-triangular in outline, convex, without axial furrows.

Illaenoides elongata novum

Figs. 8 and 9

CEPHALON semi-elliptical in outline, distinctly convex, posterior portion trilobate due to the straight dorsal furrows which extend a little more than one-third the length of the central lobe; anterior outline rounded, posterior border truncated. Glabella smooth, convex, longer than wide and with fixed cheeks forming the large part of the cephalon. Dorsal furrows well marked, shallow,

straight and practically parallel, extending a little more than one-third the length of the glabella, the anterior third of the furrows becoming indistinct, narrow, sub-lunar depressions. Fixed cheeks convex, pointed at their posterior-lateral corners, not well differentiated from the glabella except posteriorly by the short dorsal furrows. Facial sutures extending in a very gentle sigmoidal curve from the frontal margin to the eyes and then curving backward and slightly outward in a gentle concave curve to the posterior border. Eyes and free cheeks not identified. PYGIDIUM, equilateral, sub-triangular in outline, the anterior lateral angles the most pointed and the posterior angle most rounded; moderately convex, with the greatest convexity near the center; the lateral edges depressed except for the convex, raised border, and where the border is removed there is a concave band instead. This raised border is uniform in width around the sides but widens and becomes sub-pointed at the antero-lateral angles, and on turning inward from these corners narrows rapidly and disappears about one-fourth the distance to the middle of the pygidium. Only the four posterior thoracic segments known. These are broad and short, and are distinctly trilobed.

Measurements of two cephalons and two pygidia

	mm.	mm.
Length of cephalon	23	17
Maximum width between facial sutures	20	15
Length of pygidium	20	29
Width of pygidium	24	33

Remarks—Illaenoides elongata[6] is closely related to *Illaenoides triloba*, but differs in the greater length of the glabella and the short parallel arrangement of the axial furrows. This species is very abundant in the St. Clair limestone and while somewhat variable in degree of rotundity and size it is quite distinct from the other trilobites and is not likely to be confused with other known species. The pygidium is more triangular than that of *Bumastus niagarensis*.

[6] Weller, Stuart. Chicago Acad. Sc. IV, pt. II (1907).

Goldius de Koninck (*Brontes* Goldfuss 1839)

"Entire body broadly elliptical. Cephalon sub-semi-circular; glabella rapidly expanding anteriorly, lateral furrows and lobes more or less obsolescent; eyes crescentic, situated back of the middle of the head, their outer margin usually being about in line with the lateral margins of the broad anterior portion of the glabella, free cheeks larger than the fixed. Thorax with ten segments. Pygidium very large, semi-circular or semi-elliptical in outline with entire margin, usually longer than the cephalon or thorax; axis very short with radiating furrows extending from its margin cross the broad, flattened pleural surfaces toward the margin; doublure very wide."[7]

Goldius infrequens novum

Fig. 10

CEPHALON and THORAX unknown. PYGIDIUM broad, shield shaped, depressed, with indistinct pleura, and a rather straight anterior margin with the lateral parts rounded toward the back. Axial lobe short, gently convex, hemi-elliptical in shape, elongate transversely and short longitudinally, having at least one transverse furrow straight across the anterior portion, grading imperceptibly into the pleural areas rather than being bounded by axial furrows. Pleural areas flat, sloping concavely from the low convex axial lobe. Seven slightly elevated pleural ribs on each side of the pygidium diverging from the low, transversely elongate axial lobe, curving gently outward and backward but becoming obsolete before reaching the rather broad flat margin. The first three pleural furrows on each side of the axis originating at a point at or near the end of the transverse furrow, and radiating toward the periphery in a manner somewhat distinct from the other furrows which are arranged rather evenly around the axial lobe. The median rib is wider than any of the others and broadens considerably, the increase in width becoming more rapid posteriorly.

[7] Weller, Stuart. Chicago Acad. Sc. IV, pt. II, 232 (1907).

Measurements (approximate) of two pygidia

	mm.	mm.
Length of pygidium	10	6
Width of pygidium	12	10

Remarks.—While the specimens at hand are not complete, and therefore the details of the outer margins have not been observed, *Goldius infrequens* is quite distinct from the varieties heretofore described, differing especially in the arrangement of the furrows, and in the presence of the transversely elongate axial lobe. It differs from *Bronteus acamas* Hall, in having the three anterior furrows radiate from a point, in the transversely elongate, hemi-elliptical axial lobe, and in the presence of one distinct transverse furrow across the axis. Also the sub-sigmoidal character of the furrows is very much less marked, the furrows diverging almost straight from the axis rather than beginning in a curved manner.[8] It differs from *Bronteus ekwanensis* Whiteaves in having the wide and short axial lobe, in the indistinctness of that lobe, in the flatness of the pygidium both of the axis and of the pleural areas. The character of the three furrows is also distinct.[9] It differs from *Bronteus aquilonaris* Whiteaves in much the same respects except to a lesser degree.[10]

Proteus Stein 1831

Small Opisthoparia sub-elliptical in outline, the pygidium somewhat smaller than the cephalon. Cephalon semi-circular, with raised or thickened frontal margin; glabella well defined by axial furrows, rounded in frontal outline, more or less strongly convex, lateral furrows obsolete or merely indicated by dark lines on the surface. Occipital furrow well marked. Eyes prominent and near to the glabella. Thorax usually of ten convex segments. Pygidium relatively large, semi-circular, bounded by a thickened margin, the axis strongly elevated, segmented, not reaching the posterior border; pleural segments grooved by furrows.

[8] Weller, Stuart. Chicago Acad. Sc. IV, pt. II (1907).
[9] Whitfield, J. F. Geol. Survey Canada III (1884).
[10] Whitfield J. F. *Loc. cit.*

Proteus corrugatus Van Ingen

Figs. 11 and 12

CEPHALON slightly elongated, semi-circular in outline, with broad, depressed frontal border bounded anteriorly by a raised margin. Glabella slightly convex, semi-elliptical in shape but truncated at occipital furrow, extending two-thirds the length of the cephalon, slightly longer than broad, frontal margin broadly rounded, lateral margins almost parallel, straight except for very slight pair of lateral indentations or incurvings of axial furrows, posterior margin practically straight. Lateral furrows and basal lobes obsolete. Dorsal furrows well marked, uniting in broad curve around the front of the glabella and extending almost straight back to occipital furrow. Occipital furrow well marked; occipital ring arched like glabella, slightly convex or nearly flat longitudinally. Fixed cheeks very narrow, slightly convex. Free cheeks and eyes unknown. Anterior part of facial sutures "S" shaped curves joining dorsal furrows two-fifths the distance from the front of the glabella. Pre-glabellar field broad, quite flat and depressed, with raised convex border. Surface ornamented by fine, raised, anastomosing lines extending irregularly, but in general, transversely across the cephalon. PYGIDIUM, semi-circular in outline; axis strongly convex, pleural areas rather flat. Axis a half semi-cone on its side rising above the pleural portions, anterior width a little less than one-third the width of the pygidium, length about three-quarters that of the pygidium, end rounded; axial furrows straight, converging backward. Axis with six annulations, the anterior one being well marked but the others rather indistinct. Pleural area almost flat, the four broad, low simple ribs quite indistinct becoming obsolete as they curve to the flat margin. Surface ornamented by fine, raised, anastomosing lines like those on the cephalon.

Measurements of two cephalons and two pygidia

	Van Ingen's mm.	This collection mm.
Length of cranium	12	10
Length of glabella	6.7	6
Width of glabella at base	6	5.5

	Van Ingen's *mm.*	This collection *mm.*
Length occipital ring	1.5	1.5
Width frontal margin	3.7	3.5
Length of pygidium	4	5
Width of pygidium	6.5	10
Maximum width of axis	2	4

Remarks.—The original description of this species by Van Ingen is in the School Mines Quart. 23, 54–57 (1901).

Cyphaspis Burmeister, 1843

"Small, oval. Cephalon semi-circular. Genal angles produced into long spines. Glabella arched, short and narrow, bounded on all sides by a deep furrow, and with two lobes attached to the base. Cheeks broad and granulose. Eyes small and crescent-shaped. Thorax with 10 to 17 segments, which are all rounded at the extremities. Pygidium semi-circular, with 2 to 8 segments in the axis."[11]

Cyphaspis spinulocervix Foerste, 1923

Fig. 13

CEPHALON strongly convex, pustulose, broadly rounded in front and truncated behind. Glabella, almost as long as wide, length a little more than half the length of cephalon. A deep, narrow dorsal furrow extends around the front of the glabella and on either side curves to the occipital furrow making a very small convex detour around the pair of almost obsolete anterior lateral lobes and a larger convex curve around the posterior lobes, thus modifying what would otherwise be an inverted "U" shaped symmetry. Frontal-median lobe one-third longer than wide, arched, convex laterally and longitudinally, and raised above the rest of the cephalon, sub-keystone in shape, broadly rounded in front and truncated behind. The pair of faint lateral indentations, a little more than one-third the distance from the front of the glabella, probably are remnants of a pair of lateral furrows. The

[11] Grabau-Schimer, N. A. Index Fossils II, 302 (1910).

posterior pair of furrows originate at the dorsal furrows about two-thirds the distance from the front of the glabella and extend in a slightly concave curve diagonally inward and backward to the occipital furrow, which they meet half way between the middle of the occipital furrow and the dorsal furrows, become less pronounced toward occipital terminus. The anterior pair of lateral lobes almost obsolete; the posterior pair sub oval in shape, strongly convex, well separated by deep furrows from the other parts of the cephalon. Occipital ring arched laterally and convex longitudinally, a little wider than the posterior width of the median lobe but not as wide as the glabella with its two lateral lobes, only the base of the posterior occipital spine showing. Fixed cheeks small, not distinctly marked from the pre-glabellar field which extends around the front of the glabella, and is wider in front than the length (front to back) of the occipital ring, convex, bordered anteriorly by a narrow raised convex margin which curves around the front making the front of the cephalon broadly rounded in outline. Free cheeks not discovered. PYGIDIUM and THORAX not found.

Measurements of two cephalons

	mm.	*mm.*
Length of cephalon	5	4
Length of glabella	3	2.5
Maximum width of glabella	3	2.5
Maximum width of median lobe	2.5	2
Occipital width of medium lobe	2	1.5

Remarks.—This species differs from *Christyi* in having the eyes farther from the glabella, in a more elongate median glabellar lobe (*Christyi* being about as long as the maximum width of the median lobe, while this species is one-third longer), and in the less uniformly deep and rounded lateral furrows; it seems that furrows of this species are deep near the dorsal furrow and become faint toward the occipital furrow. Differs from *Intermedia* in having glabella with a more broadly rounded front thus making it "U" shaped rather than sub-"V" shaped, wider frontal cheeks and margin. Glabella more convex. It is very similar to the specimen *Cyphaspis burmeisteri* of the Bohemian Silurian Stage E in the Walker Museum, but the glabella is not as globulose, the

posterior lateral lobes are more rounded, the dorsal furrow is sharper in front of the glabella. This apparently is *Cyphaspis spinulocervix* mentioned by Van Ingen but left undescribed. School Mines Quart. 23, 35 (1901). It was later described by A. F. Foerste in Denison University Bulletin, J. Sci. Labs. Denison Univ., XX.

Corydocephalus Corda, 1847

"Cephalon broadly sub-triangular in outline, studded with tubercles, spinules or spines. Glabella well defined by the dorsal furrows, the median lobe protuberant in front and extending backward to the occipital furrow; second pair of lateral furrows obsolete, in consequence of which the first and second lateral glabellar lobes are confluent and form a single pair of large compound lobes; third pair of lateral glabellar lobes well defined, lying between the large compound anterior lobes and the occipital furrow. Behind these are a pair of basal or occipital lobes; cheeks broad, produced into a pair of curved genal spines which proceed from the sides outward and backward, the post-cephalic margin curving forward laterally to the bases of the spines. Pygidium with a thickened marginal border; axis strongly defined, elevated, connected with the marginal border posteriorly by a narrow post-axial ridge; the pleura with two segments, each of which is produced laterally into more or less elongate backwardly curving spines, the spines being produced across the surface of the pleura to the axis as strongly raised ridges."[12]

Corydocephalus depauperatus Van Ingen, 1901

Fig. 14

CEPHALON semi-circular when viewed from the front and roughly triangular from above and similar to a Maltese cross, very convex, frontal lobe strongly protuberant in front, deeply furrowed, covered with various sizes of tubercles and spines Dorsal furrows deep and strong anteriorly, circling frontal lobe and first pair of lateral lobes, then curving a little less deeply

[12] Weller, Stuart. Chicago Acad. Sc. IV, pt. II, 234 (1907).

around third pair of lobes (second pair obsolete) and around occipital lobe to occipital furrow. Frontal or median lobe expanding forward and extending around front of cephalon and under frontal margin. Minimum width of median lobe about two-thirds maximum width, and the maximum width more than one-third the width of the cephalon; strongly convex, bounded by deep, rounded, slightly diverging pair of anterior glabellar furrows. This first pair of glabellar furrows extending from frontal margin to third of furrows, and these with dorsal furrows bounding the lens-like first glabellar lobes. Second lateral furrows obsolete. Third pair of furrows strong and deep, curving inward and backward from dorsal furrow and meeting anterior pair in quadrate depression behind the frontal lobe. First lobes are lens shaped, acutely angular behind; their longer axes if prolonged would cross at occipital ring; surface of these first lobes depressed below median lobe. Third lateral lobes wedge shaped, convex, raised tuberculate, separated from each other by a quadrate depression on the axis, each median lobe bearing a spine on the lateral edge. Occipital lobes small. Occipital furrow deep and broad, bifurcating laterally to bound the small occipital lobes. Occipital ring strongly arched, elevated posteriorly. Fixed cheeks narrow in front, convex. Free cheeks and eyes not observed. PYGIDIUM and THORAX not found.

Measurements of two cephalons

	mm.	*mm.*
Length of cephalon around to frontal margin	18	7
Maximum width of median lobe	6	3
Minimum width of median lobe	4	2

Remarks.—This species is closely allied to *phlyctanoides* but the frontal margin is farther under the cephalon, and the median lobe narrows slightly more in *depauperata.* Original description: Van Ingen, School Mines Quart: 23, 57–61 (1901). Fairly common in the St. Clair limestone.

Dicranopeltis Corda, 1847

"Cephalon triangular in outline, tuberculate. First glabellar furrow curving back to the neck furrow and deep anteriorly.

Anterior lobes relatively larger and posterior lateral and occipital lobes relatively smaller than in *Corydocephalus*, while all the lateral furrows except the anterior pair are placed more transversely and the glabella is narrower posteriorly. Axis of pygidium with two annulations; lateral lobes flattened, with three pairs of grooved segments, each ending in a free point."[15]

Dicranopeltis arkansana Van Ingen, 1901

Figs. 15 and 16

CEPHALON sub-triangular in outline, very convex anteriorly, moderately convex posteriorly and laterally; breadth much greater than length; axial lobe and lateral lobes have much the appearance of three arms of a Maltese cross. Glabella well defined, and exclusive of second and third pairs of glabellar lobes sub-circular in outline; flat posteriorly but strongly convex and slightly protuberant anteriorly with deep strong dorsal furrows which extend back in convex curve to second furrows and from there in concave line to occipital furrow, becoming less marked opposite the posterior lobes. Central glabellar lobe widest along the frontal margin, the width being about equal to the distance from the front of the cephalon to the pair of coalesced lobes, strongly convex where wide but narrowing and becoming flatter posteriorly and partially coalescing with the second pair of lobes. First pair of furrows distinct, extending backward and slightly inward in concave curve, joining the inner ends of second pair of furrows and extending faintly backward to the occipital furrow. Second pair obsolete. Third pair extending outward and forward the short distance from the first furrows to the dorsal furrow. These three sets of furrows bound the sub-ovate-quadrilateral anterior pair of glabellar lobes; the long axes of these lobes, if extended, would meet at the back of the occipital ring. The posterior glabellar lobes more or less coalescing with the central lobe and also across the faint posterior extensions of the first pair of furrows and across the axis, making a sub-quadrilateral area about three times as wide as long. Occipital furrow broad,

[15] Grabau-Schimer, N. A. Index Fossils II, 310 (1910).

straight across rear of central glabellar lobe but curving backward as well as outward on each side toward genal angles and bifurcating to form the triangular occipital lobes. Occipital ring broadly arched, widest in middle and narrower laterally. Fixed cheeks convex, with abrupt anterior slope and more gentle posterior and lateral slopes. Eyes opposite first pair of lobes. Occipital lobes triangular, flattened, sloping down posteriorly, their lateral-posterior extremities reaching farther outward than the base of the glabella. PYGIDIUM, probably belonging to this species, semi-elliptical and finely tuberculate. Axis slightly less than one-third the width of pygidium at anterior margin, extending less than one-half the length of the pygidium, strongly convex, having two narrow annulations; back of these annulations the convex axis becomes depressed and narrows to a point due to the converging of the two well-marked axial furrows behind. Pleura flat, having inter-pleural furrows, three broad flat segments, produced laterally and posteriorly and ending in short, pointed spines.

Measurements of two cephalons and two pygidia

	mm.	mm.
Length of cephalon	10	8
Width of glabella	8	7
Width of frontal lobe	7	5
Length of pygidium	12	10
Width of pygidium	15	14 (approx.)

Remarks.—This species, which has been described by Van Ingen, is closely allied to *Dicranopeltis decipiens* (Winchell and Marcy) and may not be distinct from it, although the size is consistently smaller and the constriction of the axial lobe slightly less. While fragments are not at all rare in the St. Clair limestone good specimens are found with difficulty. It is closely related to *Dicranopeltis elegans* Tornquist, to judge from the figures, and is of much the same size. The glabella appears to be longer in relation to its width and the first pair of pleural and inter-pleural furrows seem to be more curved.

Arctinurus Castelnau, 1843

"Glabella completely marked off by the dorsal furrows, the median lobe extending to the occipital furrow, the first and second

lateral lobes combined and extending to the occipital furrow, the third lateral lobes squeezed out so as to be entirely absent; the second furrows obsolete or indicated by mere indentations of the first furrows; occipital lobes absent. Pygidium with one or two axial segments, the axis reaching about half way to the posterior border, the broad post-axial region with a sinuate or emarginate posterior margin; three pairs of grooved pleural segments, the two anterior pairs complete and with free points, the posterior pair complete or nearly complete."[14]

Arctinurus clairensis

Figs. 17, 18, 19, and 20

CEPHALON convex in front, flat posteriorly, finely tuberculate, with narrow, concave pre-glabellar field and raised frontal margin giving rounded outline to the front of the cranium. Frontal or axial lobe convex in front where it is wide and expanded, and flat where narrow, as well as where it is expanded in posterior part along occipital furrow. Front of glabella rounded, its outline arc of a circle having its center at the narrowest part of the axial lobe. Dorsal furrows broad and rounded, extending in convex arcs around lateral flanks of frontal glabellar lobe, and with broad concave inward and backward sweep along the sub-lunar lateral glabellar lobe, then curving toward the genal angle as it meets the occipital furrow. First glabellar pair of furrows rounded, well marked and curving inward and backward in broad concave sweep to third axial furrows which they join. Second pair of furrows absent. The third pair of furrows join the dorsal furrow to the first pair of furrows by inward and forward curve in the same arc as the first furrows, thus making the first lateral lobes sub-lunar in outline. This first pair of lobes convex. The long axes would intersect on the occipital ring if prolonged. Second lobes coalesced with the first pair. Third pair coalesce with the axial lobe. Occipital furrow broad, deep, rounded, constricted behind the glabella and expanded behind the lateral lobes. Occipital ring convex longitudinally and arched laterally,

[14] Weller, Stuart. Chicago Acad. Sc. IV, pt. II, 247 (1907).

practically straight across back of cephalon. PYGIDIUM sub-pentagonal in outline, slightly broader than long, the anterior margin almost straight and at right angles to the axis; lateral margins sub-parallel, posterior margin marked by spines, posterior angle obtuse. Axis is strongly convex extending about a third the length of the pygidium, one distinct annulation anteriorly, greatest elevation at anterior margin, sloping posteriorly, becoming more depressed and narrower: the axis like a hemi-cone on its side; post axial area expanding again due to the diverging post axial furrows along the flat posterior half of the pygidium, and ending in a pair of sharp, backwardly pointing posterior spines. Pleura nearly flat but slightly convex near the elevated axis, divided into three pairs of deeply grooved segments which are strongly bent backward, the more anterior ones extending outward almost at right angles from the axis and then bending backward until almost parallel to the axis, their terminations quite acute; free, angular, spine-like points, the inmost pair extending farthest back, the next pair a little farther forward, and the outer pair farthest forward. Between these posteriorly pointing extensions are moderately deep emarginations. The surface of the pygidium covered with numerous fine tubercles of varying sizes. HYPOSTOMA have been found in the St. Clair limestone similar to those belonging to the genus *Arctinurus*, as for example the one attributed to *Arctinurus* by Weller and the one suggested as belonging to *Lichas laciniatus* Wahlenberg. Therefore it seems quite probable that the ones described here belong to *Arctinurus clairensis*. These are gently convex, with a very indefinite line of elevation extending longitudinally through the middle, sub-elliptical in outline, broadly rounded in front by an arc equal to about a fourth of a circle with its center approximately on the elevation between the median furrows. Lateral outline rounded like arcs of the same circle but interrupted and separated from the frontal arc by the pair of indentations made by the longitudinal furrows; the two lateral borders separated from each other posteriorly by a broad and fairly deep rounded notch. A sub-elliptical, convex, anterior lobe rises in front of the median lateral furrows, reaching the front border; it is

connected with the posterior area between the inner ends of the furrows. All furrows rather indistinct. Longitudinal furrows extend from the front flanks of the anterior lobe in general nearly straight back or in a slight convex curve, disappearing about two-thirds the distance from the front of the hypostoma, the ends curving inward very slightly. The pair of median lateral furrows branching from the longitudinal furrows about one-third the distance from the front and curving convexly inward and backward, ending in shallow depressions or pits between which the convex anterior lobe and the convex posterior area coalesce. Median lateral lobes small, convex, sub-elliptical with their longer axes at such an angle that they intersect just back of the posterior notch if projected. Median lobes coalescing with the posterior area but separated from the anterior lobe by the lateral furrows. Posterior area elevated but lateral areas rather depressed. Most specimens show these characters very indistinctly and in the best examples the furrows and lobes are rounded and not in sharp relief.

Measurements of two cephalons and two pygidia and two hypostoma

	mm.	mm.
Length of head	19	13
Maximum width of axial lobe	14	9
Minimum width of axial lobe	3	2
Length of pygidium	21	11
Width of pygidium	23	13
Width of axial lobe of pygidium	7	4
Length of hypostoma	11	9
Width of hypostoma	13	10

Remarks.—This species differs from *occidentalis* in a few respects, *viz.*; the first pair of glabellar lobes are more lunar in shape and less elongate, the frontal margin is rounded in outline, concave or almost flat rather than sub-pointed; the anterior margin of the frontal lobe is also rounded broadly instead of being sub-angular. The St. Clair specimens are also smaller than those described of *occidentalis*, and the granulations are more numerous and finer. It differs from *boltoni* in having the rounded margin and rounded frontal lobe. It differs from *nereus* in the rounded margin, the broadly rounded frontal lobe, and the presence of

longer pleura, the anterior ones more nearly leaving the axis at right angles and then curving and extending backward almost parallel to the axis.

Odontopleura Emmrich, 1839

"The members of this genus are essentially like those of *Acidapis*, except in the ornamentation of the occipital segment of the head, which is entirely smooth or is marked only with a small central tubercle, no median spine ever being present. The lateral lobes of the glabella are always distinct.[15]

Odontopleura arkansana Van Ingen, 1901

Fig. 21

CEPHALON with broadly rounded anterior margin, depressed occipital area without spine, having a large central lobe shaped much like a leaf with three petals, whole surface pustulose except the posterior glabellar lobes and the occipital area, the latter having one prominent median tubercle. Glabella sub-circular but slightly longer than wide, the greatest width across the posterior lateral lobes. Central lobe extending from the raised frontal margin to the occipital furrow, coalescing with the frontal lobe and with the first pair of glabellar lobes, convex, sloping down steeply to furrow flanked by the raised frontal margin. Dorsal furrows making a semi-circle extending in broad convex curves from the front of the glabella to the occipital furrow which they meet at almost right angles, rounded, shallow, moderately well defined. First pair of lateral glabellar furrows obsolete. Second pair of furrows short, deep at outer extremities, extending obliquely inward and backward, and disappearing rapidly, not joining the other furrows or preventing the anterior and first pair of lateral lobes from coalescing with the central lobe. Third pair of furrows leave the dorsal furrows about half the distance from the front of the cephalon and curve obliquely inward and backward for about a third of their lengths and then bend somewhat more to rear and extend in almost straight courses to the

[15] Weller, Stuart. Chicago Acad. Sc. IV, pt. II, 252–253 (1907).

occipital furrow, thus cutting off the sub-elliptical posterior lobes from the central axis, rounded, deepest near the dorsal furrow, broader toward the occipital furrow. Anterior pair of lateral lobes quadrilateral, with the outer anterior corners acute and the outer posterior corners obtuse, coalescing with the central lobe, convex. Posterior pair of lobes convex, slightly depressed, sub-elliptical in outline, separated from the central lobe by the posterior extension of the third pair of lateral furrows. Occipital furrow rounded and rather indistinct. Occipital area long (front to back), wider than posterior margin of the glabella, arched behind the central lobes, with a median tubercle, the posterior margin turned downward. Cheeks narrow, curved ridges supporting a line of tubercles which bifurcate at about mid-length sending off another shorter and inner ridge supporting tubercles, the second line being practically parallel to the main row. The anterior ends of the cheeks begin at the flanks of the expansion of the frontal-central-lobe and are separated from it and from the lateral glabellar lobes by the axial furrows. Ocular ridge and free cheeks unknown. PYGIDIUM and THORAX unknown.

Measurements of one cephalon

	mm.
Length of cephalon	5.0
Length of glabella	3.8
Maximum width of glabella	3.0

Remarks.—This species differs from *Odontopleura ortoni,* Foerste in having the expanded frontal lobe, by the lack of the first pair of glabellar furrows and by the coalescing of the anterior pair of lateral lobes with the axis. It differs from *Odontopleura illinoisensis* Weller in having the expanded frontal lobe, by the coalescing of the anterior pair of furrows with the axis, the presence of a median occipital tubercle, and by having a depressed sub-oval pair of posterior lateral lobes. It differs from *odontopleura halli,* by having an expanded frontal lobe and by having a broadly rounded frontal outline to the cephalon, the coalescing of the anterior lobes with the axis, and the depressed position of the

occipital area. The cephalon is quite different from *Acidaspis evoluta* Tornquist, among other things, in the fact that the central lobe is not cylindrical, the posterior lobes are quite depressed, and the anterior pair of furrows and lobes are obsolete. The monograph by Elsa Warburg does not recognize the generic divisions of the *Acidaspidae* for the reason that the divisions proposed are artificial rather than natural. However, I am using *Odontopleura*, *Acidaspis*, and *Certocephala* as genera merely for want of a better system, and because the differences are for the most part clear, and the names are much used in publications and bibliographies.

Ceratocephala Warder, 1838

Concerning the genus *Acidaspis* Weller says, "Entire body sub-elliptical in outline, strongly trilobate, the margin of the head, thorax and pygidium bordered with spines. Cephalon usually sub-crescentiform in outline, sometimes sub-truncate in front, the genal angles produced into spines. Median lobe of the glabella elongate, extending from near the anterior margin to the occipital furrow, with two or three pairs of lateral lobes which are successively larger from the anterior to the posterior. Thorax with nine or ten segments. Pygidium with two or three annulations." About the genus *Ceratocephala* he notes, "In the characters of the glabella and cheeks the members of this genus closely resemble *Acidaspis* and *Odontopleura*, but the occipital segment bears two divergent spines which are separate at their bases."[16]

Ceratocephala depauperata Van Ingen, 1901

Fig. 22

CEPHALON transversely elliptical, nearly half as long as wide, convex, free cheeks sub-lunar in shape and concave, tuberculate. Glabella wider than long, convex, reaching from narrow, raised frontal margin to broad rounded occipital furrow. Axial lobe sub-rectangular, convex, with corners rounded, widening slightly

[16] Weller, Stuart. *Loc. cit.* 250 and 254.

toward posterior end, widest just in front of occipital furrow where the width is about half the length of the glabella, convex laterally and transversely. First pair of glabellar furrows merely pits. Second pair of furrows deep and short, directed outward and forward. Third pair deep, extending from axial lobe outward and forward a greater distance than the second. Longitudinal furrows rounded, almost straight, separating axial lobes from glabellar lobes, continuous across occipital lobe, weakest opposite second glabellar lobe. First pair of lateral glabellar lobes merely dots in the depression behind the frontal expansion. Second pair of lobes convex, extending obliquely forward from axial lobe with which they coalesce, the pair of longitudinal furrows being particularly faint. Third pair more disconnected from the axis due to stronger longitudinal furrow, convex, directed obliquely outward and forward and coalescing with the fixed cheeks. Dorsal furrows arcuate, like pair of parentheses around the glabellar lobes, weakest along anterior lateral flank of third lobes where these lobes coalesce with the cheeks. Fixed cheeks sub-lunate, convex, greatest width opposite eyes. Free cheeks sub-lunate, concave, with raised and rounded outer lateral and anterior margins, greatest width opposite the eyes. Occular ridges narrow, extending from the eyes, which are opposite the second lateral glabellar lobes, extending straight to border just in front of first pair of lobes. Eyes small, slightly elevated. Facial sutures not noticeable. Occipital furrow broad and deep, curving around end of axial lobe. Occipital ring slightly wider than axial lobe, containing two occipital, slightly diverging spines with a small node between the separate bases. Two genal spines present. The whole surface of the cephalon covered irregularly with tubercles of various sizes. THORAX and PYGIDIUM unknown.

Measurements of two individuals

	mm.	mm.
Maximum length of cephalon	9	7
Maximum width of cephalon	19	13
Maximum width of axial lobe	5	4
Distance between the eyes	14	10

Reference: Van Ingen-School Mines Quart. 23, 42–44 (1901).

Ceratocephala nodulata Van Ingen, 1901

Fig. 23

CEPHALON semi-elliptical, width over twice the length, convex, posterior slopes steep, anterior slopes more moderate; greatest width across the posterior glabellar lobes. Glabellar sub-circular, width approximately equaling length, convex both from front to back and from side to side, extending to raised frontal border; axial lobe continuous from front to occipital furrow, width equal about twice the length, strongly convex and somewhat arched. Two curved longitudinal, well marked, rounded furrows separate median lobe from the lateral lobes and also from first pair of lateral furrows. Second pair of lateral furrows rounded, extending outward and forward from longitudinal furrow, rather indistinct, short. Third pair curve outward and backward from longitudinal furrows, join dorsal furrows and with them curve back toward axis to join occipital furrow. Anterior lobes indistinct and practically obsolete, triangular areas between the border, the longitudinal furrows and the dorsal furrows. Second pair of lateral glabellar lobes sub-triangular, convex, and entirely surrounded by furrows. Third pair slightly more prominent and in most cases slightly larger than those of the second pair; entirely surrounded by rounded furrows. Dorsal furrows rounded, somewhat indistinct, question mark in shape. Occipital furrow broad, rounded, sloping concavely from glabella; has two occipital spine-like extensions, with separate bases, from the occipital furrow and ring. Cheeks long, curved, narrow, less elevated than the glabellar lobes, appear to terminate at the first glabellar lobe. Ocular ridges extend from eyes obliquely forward diminishing in width anteriorly, and making raised border for the fixed cheeks, terminating just in front of the first glabellar lobes. Separated from the rest of the fixed cheek by a pair of shallow rounded furrows which unite with the longitudinal furrows and the dorsal furrows and the first pair of glabellar furrows. Free cheeks unknown. Facial sutures indistinct in the specimens studied. Surface of the cranium minutely granular with two to four tubercles on each ocular ridge, three on

each fixed cheek, and one on the summit of each lateral glabellar lobe, and several scattered irregularly over the axial lobe. PYGIDIUM and THORAX unknown.

Measurements of two cephalons

	mm.	mm.
Length of cranium	5	5
Width of cranium	8	9
Maximum width of glabellar	5	6
Maximum width of axial lobe	2	2.5

Remarks.—The original description of this species notes one tubercle on the occipital region and one large knob on the posterior half of the glabella, but the specimens collected do not show this to be a constant or prominent feature. Otherwise these specimens seem to correspond very closely with the description by Van Ingen: School of Mines Quart. 23, 44–48 (1901).

PLATE I

HYPOPARIA AND OPISTHOPARIA FROM THE ST. CLAIR LIMESTONE, ARKANSAS

Fig. 1. *Ampyx magarensis* Van Ingen. Cephalon.
Fig. 2. *Bumastus ioxus* Hall. Cephalon.
Fig. 3. *Bumastus ioxus* Hall. Pygidium.
Fig. 4. *Bumastus cf. ioxus* Hall. Small cephalon.
Fig. 5. *Bumastus cf. ioxus* Hall. Medium sized cephalon.
Fig. 6. *Bumastus clairensis* novum. Cephalon.
Fig. 7. *Bumastus graftonensis* Meek & Worthem. Cephalon.
Fig. 8. *Illaenoides elongata* novum. Cephalon.
Fig. 9. *Illaenoides elongata* novum. Pygidium.
Fig. 10. *Goldius infrequens* novum. Pygidium.
Fig. 11. *Proteus corrugatus* Van Ingen. Cephalon.
Fig. 12. *Proteus corrugatus* Van Ingen. Pygidium.
Fig. 13. *Cyphaspis spinulocervix* Foerste. Cephalon.
Fig. 14. *Corydocelphalus depauperatus* Van Ingen. Cephalon.
Fig. 15. *Dicranopeltis arkansana* Van Ingen. Cephalon.
Fig. 16. *Dicranopeltis arkansana* Van Ingen. Pygidium.
Fig. 17. *Arctinurus clairensis* novum. Cephalon.
Fig. 18. *Arctinurus clairensis* novum. Cephalon.
Fig. 19. *Arctinurus clairensis* novum. Pygidium.
Fig. 20. *Arctinurus clairensis* novum. Hypostoma.
Fig. 21. *Odontopleura arkansana* Van Ingen. Cephalon.
Fig. 22. *Ceratocephala depauperata* Van Ingen. Cephalon.
Fig. 23. *Ceratocephala nodulata* Van Ingen. Cephalon.

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THE ORDOVICIAN AND SILURIAN OF AMERICAN ARCTIC AND SUBARCTIC REGIONS

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1. INTRODUCTION AND ACKNOWLEDGMENTS

The geological explorations of Lauge Koch, in Greenland, followed by the paleontological investigations of Gustaf Troedsson and Christian Poulsen, have resulted in a much clearer grasp of some of the problems of Ordovician and Silurian geology in American Arctic and Subarctic areas than was possible without the information thus obtained. Now that it has been demonstrated that the Arctic offers a large field for geological exploration to persons properly qualified for such work, it may be assumed that the next few years will show a corresponding further increase of our knowledge of Arctic geology. It has seemed desirable, therefore, to bring together some of the more salient facts regarding Arctic and Subarctic geology now known and to state some of the conclusions that apparently may be drawn from these facts. This is true especially of conclusions that are likely to prove controversial, since nothing is so likely to put an end to conclusions not warranted by the facts as the accumulation of additional facts, especially if additional facts are sought with the object of learning whether previous conclusions are warranted or not.

The present writer is of the opinion that some of our conclusions regarding the stratigraphy of northern Ordovician and Silurian formations need considerable clarification, and he is by no means of the opinion that he has found the solution, but the following pages are presented in the hope that they may be of assistance, at least by way of focussing attention on those where he is most in doubt.

He is under great obligations to Christian Poulsen of Copenhagen, Prof. Johan Kiär of Oslo, and Gustaf Troedsson and Herman Hedström of Stockholm for the privilege of studying the collections under their charge. Also to Lauge Koch for communications on the progress of his work in northern Greenland. He wishes to express special thanks for the grant from the Marsh Fund which permitted his undivided attention to the subject for several months.

2. PROPOSED CHANGES IN THE NOMENCLATURE OF ORDOVICIAN CEPHALOPODS FROM SOUTHERN MANITOBA

The most interesting part of the fauna discovered in the Ordovician formations of southern Manitoba undoubtedly is its cephalopod content. This gave rise to several papers by Whiteaves, and later to the studies by the present writer. Recently is has seemed desirable to propose a number of new genera, where references to older genera were likely to prove misleading as to actual relationships, and in studies now in progress several more changes are advocated. Under these circumstances it may be useful for the writer to present here a list of the species described by Whiteaves, with such changes of nomenclature as have been proposed and as now advocated in addition.

Cyclendoceras (subannulatum Whiteaves) whiteavesi Foerste
Narthecoceras crassisiphonatum (Whiteaves)
Narthecoceras simpsoni (Billings)
Armenoceras richardsoni (Stokes)
Actinoceras bigsbyi (?) Bronn
Ormoceras allumettense (Billings)
Paractinoceras canadense (Whiteaves)
Whiteavesites (Orthoceras) winnipegensis (Whiteaves)
Cycloceras selkirkense (Whiteaves)
Lambeoceras lambi (Whiteaves)
Garryoceras semiplanatum (Whiteaves)
Billingsites costulatum (Whiteaves)
Diestoceras nobile (Whiteaves)
Diestoceras apertum (Whiteaves)
Dowlingoceras gracile (Whiteaves)
Cyrtogomphoceras magnum (Whiteaves)
Cyrtogomphoceras whiteavesi (Miller)
Cyrtogomphoceras (?) intermedium (Whiteaves)
Westonoceras manitobense (Whiteaves)
Winnipegoceras laticurvatum (Whiteaves)
Charactoceras plicatum (Whiteaves)
Discoceras canadense (Whiteaves)
Wilsonoceras (Trochoceras) mccharlesi (Whiteaves)
Selkirkoceras cuneatum Foerste (Actinoceras richardsoni, Whiteaves, Trans. Royal Soc. Canada, 9, pl. 9, figs. 3, 3a, 1892.

Some of these genera were proposed in Contrib. Mus. Pal. Univ. Michigan, vol. 3, 1928, as part of the series of papers by Gould, Foerste, and Hussey on the "Contributions to the Geol-

ogy of Foxe Land, Baffin Island." Others have appeared in earlier papers. The names *Kochoceras* and *Calhounoceras* were proposed by Troedsson, and species belonging to these genera are known from the Ordovician of southern Manitoba. This list will assist somewhat in explaining the references to Ordovician cephalopods in the following paragraph.

3. THE DISTRIBUTION OF THE SOUTHERN MANITOBA ORDOVICIAN CEPHALOPOD FAUNA

Between thirty and forty years ago Whiteaves described or identified 27 species of cephalopods from the Ordovician of southern Manitoba, 19 of which he recognized as new. A study of all the material available at present indicates the presence of 49 species of which 41 are named; 27 of the latter are identified with species already described, and 13 are regarded as distinct from those previously named, and are here described as new. These 48 species belong to 28 genera, of which 12 so far have not been identified south of Canada. These 12 are *Garryoceras, Whiteavesites, Dowlingoceras, Kochoceras, Selkirkoceras, Paractinoceras, Narthecoceras, Calhounoceras, Winnipegoceras, Westonoceras, Wilsonoceras,* and *Cyrtogomphoceras.* Six of the remaining genera are known also from the United States, but there they occur only in the more northern states. These 6 are *Billingsites, Ephippiorthoceras, Charactoceras, Discoceras, Lambeoceras,* and *Diestoceras.* Of these 18 genera 9 occur as far north as the northern margin of Kane Basin, along the northwestern margin of Greenland. These are *Narthecoceras, Ephippiorthoceras, Charactoceras, Lambeoceras, Kochoceras, Calhounoceras, Westonoceras, Cyrtogomphoceras,* and *Diestoceras.* To this list should be added *Huronia,* which in strata of Ordovician age is known only from northern areas, occurring in Greenland, in the area west of Hudson Bay, in southern Manitoba, and from the Big Horn range of Wyoming. Moreover, that section of the genus *Cyclendoceras* in which the annulations are relatively numerous and close together is known at present only from southern Manitoba and from that part of the Rocky Mountain Richmond which is regarded as having northern affinities. Finally, the genus

Apsidoceras, although not known from southern Manitoba, occurs in northern Greenland, west of Hudson bay, and on Anticosti Island.

In general, therefore, the Ordovician cephalopod fauna of southern Manitoba may be regarded as a northern fauna, chiefly of Canadian and American Arctic distribution, and quite distinct from the contemporaneous Ordovician cephalopod faunas of the greater part of the eastern half of the United States. It is this Arctic relationship of the southern Manitoba cephalopod fauna which gives it special interest at the present time, and which makes it desirable to bring together all available data having any bearing on it.

This fauna occurs over a wide area. From the southern part of Manitoba to Kane Basin, alone the northwestern coast of Greenland, is a distance of about 2100 miles. In an east and west direction, between the northeastern part of Foxe Land, on the southwestern side of Baffin Island, and the northern arm of Great Slave Lake the distance is 1200 miles. The fossil locality northeast of Foxe Land lies 1200 miles northeast of southern Manitoba. Igloolik Island is 320 miles northwest of the Foxe Land fossil locality. Lake Timiskaming is about 800 miles almost directly east of southern Manitoba. The Ordovician area west of Hudson Bay is 830 miles a little east of north from southern Manitoba; and the Ordovician area on the north arm of Great Slave Lake is about 830 miles northwest of the Ordovician area west of Hudson Bay.

The fauna of this immense area is diversified, but everywhere contains elements of the typical southern Manitoba fauna. At the fossil locality northeast of Foxe Land, the genera *Ephippiorthoceras*, *Westonoceras*, and *Cyrtogomphoceras* occur, apparently associated with *Lambeoceras* and a species of *Leurorthoceras* closely similar to *Leurorthoceras ruedemanni* described by Troedsson from northwestern Greenland. On Igloolik Island two species of *Kochoceras* were found. On Lake Timiskaming *Narthecoceras* and *Dunleithoceras* occur, the latter represented by a species known elsewhere only west of Hudson Bay. In the Hudson Bay area itself the genera found include the southern

Manitoba genera *Billingsites*, *Ephippiorthoceras*, *Kochoceras*, *Westonoceras*, *Cyrtogomphoceras*, *Diestoceras*, and *Huronia*; also the genus *Huronia* which is not known in southern Manitoba, but which occurs also in northwestern Greenland. In addition there are three genera, *Antiplectoceras*, *Parksoceras*, and *Shamattawoceras*, known so far only from the Hudson Bay region. From the north arm of Great Slave Lake only *Kochoceras* is known, among characteristic genera.

4. THE INFLUENCE OF THE CANADIAN SHIELD ON THE DISTRIBUTION OF THE EARLIER PALAEOZOIC FAUNAS

One of the most interesting features connected with this wide distribution of the southern Manitoba fauna is its occurrence not only on the margin of an enormous area of pre-Cambrian strata known as the Canadian shield, but also in regions more central within the shield. None of the earlier Ordovician or Cambrian strata have a similar wide spread distribution. On the contrary, all of these earlier strata are confined to the margin of the Canadian shield, indicating that this shield was distinctly elevated above sea level already at the beginning of Palaeozoic deposition. The extreme northern margin of the shield is indicated along the Kane Basin in northern Greenland and Ellesmereland by the occurrence of the Lower and Middle Cambrian, the Lower (?) and Upper Ozarkian, and the Upper Canadian. *Maclurites magnus*, a Chazyan gasteropod, was identified by Etheridge from the western shore of Kane Basin, but this identification needs confirmation, since *Maclurites* and *Maclurina* are fairly common fossils in the northward extension of the southern Manitoba fauna, which is distinctly of later than Chazyan age. Along the eastern shore of Greenland, mid-way between its northern and southern ends, Lower Cambrian and Middle Ozarkian strata were found by Lauge Koch, in King Oscar and Franz Joseph Fjords.

The Chazyan is known definitely only from areas south of the Canadian shield. It occurs in Newfoundland, the Mingan Islands, in the vicinity of the cities of Quebec, Montreal, and Ottawa, and in the northeastern part of the state of New York.

At some of these localities lower horizons are present: Cambrian and Canadian in Newfoundland; Canadian in the Mingan Islands; and Ozarkian and Canadian near the cities of Quebec, Montreal, and Ottawa, also in the northeastern part of the state of New York. In Wisconsin the Cambrian, Ozarkian, and Canadian are followed by St. Peters sandstone and the typical Chazyan is absent. Similar strata are exposed in Minnesota.

The most western part of the Canadian shield exposed at present is bounded by Lake Winnipeg, Slave River, and the Mackenzie River. Along Lake Winnipeg and the north arm of Great Slave Lake the pre-Cambrian rocks which form the Canadian shield are overlaid directly by strata containing the peculiar cephalopod fauna mentioned at the beginning of this paper. These bodies of water, however, can not be considered as near the western boundary of the Canadian shield during Cambrian, Ozarkian, Canadian, or Chazyan times, since no strata of that age have been discovered anywhere along this present western limit of pre-Cambrian rocks. The western limit of the Canadian shield during early Palaeozoic times probably lay far westward, under the present cover of Devonian, Cretaceous, and other strata, within the great plains of the Mackenzie Valley.

In a similar manner, the western boundary of the Canadian shield during early Paleozoic times probably lies buried beneath the Silurian, Carboniferous, and Triassic of the more western islands of the American Arctic Archipelago.

5. MOHAWKIAN STRATA ON THE CANADIAN SHIELD

At Port Burwell, west of Cape Chidley at the northern extremity of Labrador, erratic blocks of dark gray impure limestone contain *Endoceras chidleyense*, *Cyclendoceras boreale*, *Plectoceras lowi*, and *Eurystomites chidleyense*. This appears to be a Mohawkian fauna.

From some unknown locality on Boothia Felix or King William Land, brought back by Captain Amundsen, there were obtained *Leurorthoceras hanseni*, *Actinoceras amundseni*, *Spyroceras aquilonare*, and *Plectoceras foerstei*, the last two described by Troeds-

son. This also is regarded as a Black River fauna. Among other species listed as belonging to the same fauna are *Receptaculites oweni, Halysites* sp., *Columnaria* sp., *Maclurea* sp., and *Gonioceras occidentale.*

From Norman Lockyer Island, north of the east end of Bache Peninsula, in the southwestern part of Kane Basin, east of the middle of Ellesmereland, *Gonioceras occidentale* was identified, associated with *Halysites gracilis, Calapoecia canadensis, Triplecia, Thaleops ovata,* and *Nileus.*

The genus *Gonioceras* is known at present only from Chazyan and Black River horizons. Its place in Richmond strata is taken by *Lambeoceras* which is unknown at the lower horizons. Since the genus *Lambeoceras* was proposed only recently, it is desirable that the specimens identified as *Gonioceras occidentale* from the Boothia Felix—King William Land area and from Norman Lockyer Island be reexamined to be certain that they do not belong to the genus *Lambeoceras.*

At Cape Calhoun, at the northern margin of Kane Basin in the northwestern part of Greenland, four species of *Gonioceras* and four species of *Lambeoceras* have been found. Of these, the four species of *Gonioceras* have all been placed by Troedsson in the Mohawkian, while all of the species of *Lambeoceras* have been placed in the Richmond. The strata here identified as Richmond evidently are the northern extension of that Ordovician fauna which was described by Whiteaves from southern Manitoba.

This southern Manitoba fauna, identified as Richmond by Troedsson, was regarded as belonging to the Galena phase of the Trenton by Whiteaves, Dowling, and many others, and this accounts for the identification as Trenton of other upper Ordovician strata found on the Canadian shield, such as those on the western shore of Hudson Bay, in the Lake Timiskaming area, and on Frobisher Bay. It is not likely that the change of identification from Trenton to Richmond will be made without hesitation by many investigators, but if this leads to a careful reinvestigation of the differences between Trenton and Richmond faunas, paleontological science will be the gainer.

6. STRATIGRAPHY OF SOUTHERN MANITOBA ORDOVICIAN

In his report on the geology of the west shore and islands of Lake Winnipeg, published in 1900, Dowling divided the Ordovician strata of this area into the following formations, listed in descending order:

Stony Mountain formation
Upper Mottled limestone
Cat Head limestone
Lower Mottled limestone
Winnipeg sandstone

Of these, the Stony Mountain formation was correlated with the Richmond group, while the Upper Mottled limestone, Cat Head limestone, and Lower Mottled limestone was regarded by both Whiteaves and Dowling as corresponding to the Galena phase of the Trenton, as exposed in the Upper Mississippi Valley. Regarding the Winnipeg sandstone Dowling stated that "the fossils give no definite information as to the age of the beds, but suggest a passage from Black River to Trenton."

In a study of the cephalopods brought back by Laurence M. Gould from Foxe Land on the southwestern side of Baffin Island, the writer found it inconvenient not to have a single name for the strata regarded by Dowling as belonging to the Galena phase of the Trenton, and proposed for the same the collective name Red River formation. For the Upper Mottled limestone he proposed the name Selkirk limestone, in view of the numerous fossils collected from this horizon at East Selkirk, Lower Fort Garry, Tyndall, and elsewhere in the vicinity of Selkirk. For the Lower Mottled limestone he proposed the name Dog Head, from Dog Head, on the west shore of Lake Winnipeg, this being one of the important fossil localities containing the fauna of the Lower Mottled limestone. This results in the following list of strata, in descending order:

		feet
Stony Mountain formation		100+
Red River formation	Selkirk limestone	130
	Cat Head limestone	70
	Dog Head limestone	70
Winnipeg sandstone		100+

7. THE STONY MOUNTAIN FORMATION

In his Geology of Anticosti Island, Twenhofel not only correlates the Stony Mountain formation with the Vaureal of Anticosti but definitely correlates it with zones 3, 4, and 5 of the Vaureal, the total number of zones being 6. Out of a list of 53 species from Stony Mountain, published by Dowling, 33 occur also in the Richmond of Anticosti, and of the latter 22 are considered index fossils of the Richmond. The first occurrence of fossils belonging to the English Head and Vaureal members of the Richmond west of Anticosti is on Snake Island in Lake St. John, and a trace of this fauna occurs south of Three Rivers and in the area east of Ottawa. Traces of the Vaureal fauna occur also at Spring Valley, Minnesota; Iron Ridge, Wisconsin: and Wilmington, Illinois. Twenhofel regards the Richmond faunas of Anticosti as being of North Atlantic origin, and that these Anticosti faunas were carried into the Mississippian sea by westward trending currents. This westward trend, on the contrary, prohibited the species characteristic of the interior parts of the American continent from reaching Anticosti.

Elements of the Stony Mountain fauna occur also in the Shammattawa limestone in the area southwest of Hudson Bay, the distance being 420 miles northeast of the southern end of Lake Winnipeg. These elements include *Streptelasma trilobatum;* an undescribed species of *Streptelasma* having the convex side flattened; a form of *Dinorthis,* resembling *subquadrata,* but with unusually large radiating striae; a large coarse form of *Rhynchotrema,* resembling *capax;* and *Strophomena fluctuosa.* Among the cephalopods, *Apsidoceras boreale, Billingsites boreale,* and *Ephippiorthoceras dowlingi* belong to genera represented by closely related species in the Richmond of Anticosti; however, related species occur also in the underlying Red River formation in southern Manitoba and northwestern Greenland. Such species as *Huronia septata, Kochoceras shammattawaensis,* and *Winnipegoceras* (?) *contractum* also have their affinities in the fauna of the Red River formation, so that the Shammattawa limestone is less sharply limited from the Red River formation

beneath than is the Stony Mountain formation. Possibly the Shammattawa limestone represents a lower horizon than the latter.

8. APPROXIMATE AGE OF RED RIVER FORMATION

The chief interest of Twenhofel's very exact correlation of the Stony Mountain formation of southern Manitoba with zones 3, 4, and 5 of the Vaureal member of the Richmond on Anticosti lies in the evidence thus offered that the Red River formation of southern Manitoba is of earlier age than the Vaureal.

On the other hand, there is evidence that the Red River formation is of later age than the Prosser limestone. This Prosser limestone is widely distributed over the Upper Mississippi region and extends thence eastward into the area north of the eastern part of Manitoulin Island and into the Saugeen Peninsula southeast of Georgian Bay. In this more eastern area the pre-Cambrian rocks forming the southern margin of the Canadian shield are overlaid directly by the Lowville, followed by the Decorah, the Curdsville, and the upper Prosser. All of these formations are limited to the southern border of the shield. None occur as outliers on the surface of the shield itself, at a distance from its southern margin. The Red River formation is the first Ordovician formation which not only transgresses the borders of this shield but covers extensive areas on its surface. It evidently was deposited during a period of wide-spread submergence of this shield, following a long period of elevation permitting only marginal deposits. Hence the Red River formation is regarded as of later age than the Lowville, Decorah, and Prosser, notwithstanding the fact that its fauna appears to have invaded from the north, rather than from the south, at least in part.

9. MOHAWKIAN AFFINITIES OF RED RIVER FORMATION

About 160 species have been identified from the Red River formation, chiefly by Whiteaves and Dowling. Of these about one-third were originally described from this Red River formation as new species. The other two-thirds were identified with species already known elsewhere. Of the latter, a few species

were identified with Richmond forms, but by far the greater number were identified with species having Mohawkian affinities. Among the Mohawkian species many occur in both the Black River and Trenton, and are widely distributed in both the United States and Canada. Among those more restricted in their vertical distribution the great majority are Trenton. Of those Trenton forms regarded by the writer as most useful for purposes of correlation 8 are characteristic of the Trenton of New York and that part of Canada which lies northeastward from New York; 27 are characteristic of the Trenton of the Upper Mississippi region, occurring more specifically in its Prosser member; and 22 species occur in both areas. To that extent the Red River fauna may be said to be of Upper Mississippi Trenton or of Prosser affinities.

In Minnesota and northern Iowa the Prosser formation is followed by the Stewartville dolomite; in neighboring states this dolomite is not differentiated from the Galena, which in the Upper Mississippi region is a general name for the combined Trenton. This Stewartville dolomite is the conspicuous *Maclurina-Maclurites* horizon of the Upper Mississippi valley Trenton. It includes the species *Maclurina cuneata*, *Maclurina manitobensis*, and *Maclurites crassus*. All three of these species were identified by Hussey from the eastward extension of the Red River formation in the northeastern part of Foxe Land and by Schuchert at the head of Frobisher Bay, both localities in southern Baffin Island. *Maclurina manitobensis* and *Maclurites crassus* were identified by Troedsson from the northwestern part of Greenland, along the northern margin of Cape Calhoun. And *Maclurina manitobensis* alone is listed from all three members of the Red River formation in southern Manitoba. Most interesting of all is the citation of *Tripteroceras lambei* Whiteaves from the Stewartville dolomite at Stewartville, Minnesota, by John M. Clarke. This is the genotype of *Lambeoceras*. Three additional species of *Lambeoceras* occur in the northward extension of the Red River formation in northwestern Greenland, and one species, *Lambeoceras richmondensis* Foerste, was described from the Whitewater member of the Richmond at Rich-

mond, Indiana. However, this identification of the Stewartville specimen as *Lambeoceras lambei* will need verification in view of the fact that the figure published by Clarke does not show the characteristic outward curvature of the sutures of the septa on approaching the crests of the lateral saddles, and the siphuncle of this specimen is described as moniliform, whereas that of typical *Lambeoceras* is more nearly nummuloidal. As drawn, the Minnesota specimen looks more like a genuine *Tripteroceras*.

While the general Mohawkian facies of a considerable part of the fauna of the Red River formation is readily admitted, this does not lead necessarily to the conclusion that the Red River formation itself is Mohawkian. It must be remembered that the Richmond formation also presents many fossils whose nearest relatives are Mohawkian. In fact, this recurrence of Mohawkian types in the Richmond, after a withdrawal during Cincinnatian times from the Ohio-Indiana-Kentucky area, is one of the most interesting features of the Richmond in those states.

10. RICHMOND AFFINITIES OF RED RIVER FORMATION

Although by far the larger part of the Red River fauna shows distinctly Mohawkian relationships, there are a few species which are more directly indicative of the Richmond. Among these are *Rhombotrypa subquadrata, Ptilodictya flagellum, Dinorthis subquadrata, Rhynchotrema capax, Strophomena fluctuosa, Strophomena planodorsata, Leptaena unicostata, Ceraurinus icarus, Isotelus iowensis,* and *Homotelus gratiosus.* In this list a number of species are included from among those identified by Troedsson in the northward extension of the Red River formation in the area north of Kane Basin in northwestern Greenland.

However, the most interesting examples of species from the Red River formation which have Richmond affinities occur among the cephalopods. This is true especially of such species as *Billingsites costulatum* (Whiteaves), *Billingsites borealis* (Parks), *Apsidoceras boreale* Foerste, *Apsidoceras elegans* Troedsson, *Ephippiorthoceras* cf. *formosum* (Billings), *Ephippiorthoceras dowlingi* Foerste, *Ephippiorthoceras modestum* Troedsson, *Ephippiorthoceras compressum* Foerste, *Ephippiorthoceras baffinense* Foerste,

Charactoceras plicatum (Whiteaves), *Charactoceras schucherti* Foerste, *Charactoceras rotundum* Troedsson, *Charactoceras baeri* (Meek and Worthen), *Lambeoceras lambei* (Whiteaves), *Lambeoceras princeps* Troedsson, *Lambeoceras nudum* Troedsson, *Lambeoceras magnum* Troedsson, *Lambeoceras boreum* Troedsson, *Diestoceras apertum* (Whiteaves), *Diestoceras whiteavesi* Foerste, *Diestoceras gibbosum* Foerste, *Diestoceras pyriforme* Troedsson, *Diestoceras schucherti* Foerste, *Huronia occidentalis* Foerste, *Huronia septata* Parks, and *Huronia arctica* Troedsson. All of these species have their nearest relatives in the Richmond.

Billingsites occurs in the Richmond of Anticosti, Michigan, Indiana, Ohio, and in the Maquoketa phase of the Richmond in eastern Iowa, where it was found recently by Prof. A. O. Thomas. *Apsidoceras* occurs in the Richmond of Anticosti. *Ephippiorthoceras* is represented by 5 species in the Richmond of Anticosti. That type of *Charactoceras* represented by the first three species cited above is known only in the Red River fauna, but *Charactoceras baeri* was described originally from the Richmond of Indiana, and closely similar specimens occur in the Fernvale member of the Richmond at Wilmington, Illinois, and at Cape Girardeau, Missouri; also in the Maquoketa phase of the Richmond in Iowa. The closely related *Charactoceras* hercules (Billings) occurs in the Richmond of Anticosti. *Lambeoceras richmondensis* Foerste was described from the Whitewater member of the Richmond in Indiana. The peculiar forms of *Diestoceras* listed above, incurved along the margin of the aperture, are represented in the Vaureal and Ellis Bay formations of Anticosti by *Diestoceras strangulatum* Foerste and *Diestoceras arenicolum* Foerste. *Huronia* is not known outside of zones correlating with the Red River formation anywhere lower than the Jupiter formation of Anticosti, whose fauna has a Clinton aspect. The work of Ulrich and Twenhofel definitely excludes the Jupiter formation from the upper or Lockport division of the Niagaran. In Michigan *Huronia* is not known below the Manistique formation.

To the preceding list should be added *Cyclendoceras whiteavesi* Foerste which is so closely similar to an undescribed species from

the Maquoketa of Iowa that it will require close study to determine whether they are identical or distinct. *Spyroceras aquilonare* (Troedsson) appears closely related to *Spyroceras microlineatum* Foerste from the Vaureal member of the Richmond on Anticosti. *Discoceras canadense* Whiteaves appears to be the only representative of the genus *Discoceras* in America. In the Ringerike area of Norway several species in addition to the genotype masquerade under the same name, *Discoceras antiquissimum* (Eichwald). All of these occur at the Gasteropod horizon which correlates most readily with the Silurian part of the *Leptaena* limestone for which the term Kallholn limestone has been proposed recently. This Kallholn limestone correlates best with the Ellis Bay formation of Anticosti. Like the latter it contains species of *Billingsites* and *Apsidoceras* associated with other fossils of a distinctly Silurian aspect. So, by a rather roundabout line of reasoning, *Discoceras canadense* also may be grouped among Red River species having relationships with strata of Richmond or later than Richmond age, rather than with strata of an age corresponding to the Galena phase of the Trenton. The genus *Danoceras*, described by Troedsson from northwestern Greenland with *Danoceras ravni* as the genotype, is probably identical with *Hyperoceras* described by Foerste from the English Head member of the Richmond of Anticosti. The Anticosti report had been written years before the Greenland report, but not published until 1928.

11. INTRODUCTION OF NUMEROUS NEW GENERIC CEPHALOPOD TYPES IN RED RIVER FORMATION

One of the most striking features of the cephalopod fauna of the Red River formation and of the closely allied Shammattawa limestone is the introduction of a remarkably large number of new generic types, equalling almost thirty in number. Among these, the following have been discussed already in the preceding section: *Apsidoceras*, *Billingsites*, *Charactoceras*, *Danoceras*, *Diestoceras*, *Discoceras*, *Ephippiorthoceras*, *Huronia*, and *Lambeoceras*, genera whose relationships are distinctly with the Richmond or later formations. Among other genera introduced in

the Red River formation or in the Shammattawa limestone are the following, their geographical range being indicated by the letters M, H, T, C, I, Fo, and Fr, signifying Manitoba, Hudson Bay, Lake Timiskaming, Cape Calhoun in northwestern Greenland, Igloolik Island, Foxe Land in southwestern Baffin Island, and Frobisher Bay in the southeastern part of Baffin Island.

Antiplectoceras (H), *Calhounoceras* (C, M), *Cyrtogomphoceras* (M, H, C, Fo), *Dowlingoceras* (M), *Eskimoceras* (C), *Garryoceras* (M), *Kochoceras* (M, H, C, I), *Narthecoceras* (M, T, C), *Paractinoceras* (M), *Parksoceras* (H), *Shammattawaceras* (H), *Selkirkoceras* (M), *Tuyloceras* (H), *Westonoceras* (M, H, C, Fo, Fr), *Whiteavesites* (M), *Wilsonoceras* (M), and *Winnipegoceras* (M).

In the case of *Winnipegoceras* it is possible that this genus should include not only the genotype, *Winnipegoceras laticurvatum* (Whiteaves), but also species with much shorter living chambers, such as *Winnipegoceras dowlingi* (Foerste) from southern Manitoba, *Westonoceras* (?) *contractum* Foerste and Savage from Hudson Bay, and *Oncoceras tumidum* Schuchert from Frobisher Bay. *Maelonoceras reclinatum* Troedsson, from Cape Calhoun, may be related. *Westonoceras latum* Troedsson, from Cape Calhoun, differs from this group of species in the straighter course of the sutures of its septa.

Three additional species are of interest in this connection. They are *Rizoceras coronatum* Foerste from Hudson Bay, *Oxygonioceras* (?) *latum* Foerste from southern Manitoba, and *Leurorthoceras* (?) *baffinense* Foerste from Foxe Land in southwestern Baffin Island. The *Rizoceras*, with traces of color markings, is a breviconic, nearly straight form, having its affinities with numerous Silurian species in Bohemia, although of much earlier age. The species provisionally placed in *Oxygonioceras* belongs to a generic type unknown in typical *Oxygonioceras*. In the latter the concave side of the conch is distinctly rounded in cross-section, while in the southern Manitoban species here called *latum* the cross-section of this dorsal side is acute, similar to the cross-section of the ventral side. This places it in a distinct generic group, unnamed on account of lack of sufficient information about the location and structure of its siphuncle. *Cyrtoceras* (?)

cuneatum Whiteaves, from the Silurian of Stonewall, in southern Manitoba, probably is a typical species of *Oxygonioceras*, comparable with those found in the Silurian of Bohemia. *Leurorthoceras* (?) *baffinense*, provisionally referred to *Leurorthoceras*, unquestionably is closely related to *Leurorthoceras* (?) *ruedemanni* Troedsson, and both represent a generic type not known in Mohawkian rocks elsewhere. Whether these two species really belong to *Leurorthoceras* is not so certain. Another generic type is represented by *Oncoceras intermedium* Whiteaves, provisionally referred to *Cyrtogomphoceras*, with which it agrees in having a large endogastric nummuloidal siphuncle, endogastric in location. It differs. however, in having its dorsal outline gently but distinctly concave along its entire length, instead of distinctly, though moderately, gibbous along the upper part of the phragmacone and the lower part of the living chamber. *Cyrtogomphoceras curvatum* Troedsson may be related, but its ventral outline is more humped at the fourth camera below the living chamber.

This large influx of new generic types of cephalopods, not all well enough understood to receive new generic names, may be explained in either of two ways: as due to the derivation of these new types from a distinct oceanic basin, also of Mohawkian age, or as due to the influx of Richmond forms, developed elsewhere, into a sea whose fauna still retained its Mohawkian facies. Under the first interpretation, the Red River fauna is regarded as of Mohawkian age; under the second it could be regarded as of Richmond age. It is the second interpretation which is favored by the writer.

12. RED RIVER CEPHALOPODS WITH MOHAWKIAN AFFINITIES

Gonioceras and *Vaginoceras* are genera known so far only from Chazyan and Black River formations. Those species identified from Cape Calhoun in northwestern Greenland suggest that here a Black River horizon may exist below the northward extension of the Red River formation. From Lake Timiskaming, *Vaginoceras multitubulatum* (Hall), *Cyrtocerina schoolcrafti* Clarke, and *Orthoceras fusiforme*, all Black River species, are cited by Hume from the Liskeard formation, which contains also the char-

acteristic Red River cephalopods *Narthecoceras crassisiphonatum* Whiteaves and *Dunleithoceras cordatum* (Parks). The writer has not seen the specimens giving rise to the first two identifications, but *Dunleithoceras cordatum* was described originally from loose material at the mouth of the Nelson River, on the southwestern shore of Hudson Bay, and its nearest relative appears to be the species originally described as *Cyrtoceras dunleithense* by Miller and Gurley from the Platteville member of the Black River in Illinois. *Clinoceras exiguum* (Billings), identified by Schuchert from the head of Frobisher Bay in southeastern Baffin Island, is closely allied to *Clinoceras mumiaforme* (Whitfield), both of which are Mohawkian species. *Troedssonoceras striatum* Troedsson and *Troedssonoceras lineatum* Troedsson, both from Cape Calhoun, find their nearest relatives in *Orthoceras turbidum* Hall and Whitfield, the genotype of *Troedssonoceras*, originally described from the Fairmount member of the Maysville formation at Cincinnati, Ohio.

These species are regarded here as relicts of the Mohawkian fauna, surviving in strata already witnessing the introduction of Richmond types of cephalopods.

13. THE CORAL CONTENT OF THE RED RIVER FORMATION

The corals are among the most important factors giving the Red River formation a Richmond aspect. This is owing chiefly to their vigorous growth, their abundance, and their wide distribution. Among those which occur both in the lower or Dog Head member and in the upper or Selkirk member of the Red River formation in southern Manitoba are *Calapoecia canadensis*, *Columnaria alveolata*, *Halysites gracilis*, *Protaraea magna*, and *Streptelasma robustum*. *Protaraea vetusta* is cited from the Dog Head member and from the Stony Mountain formation which directly overlies the Red River formation. *Columnaria* (*Palaeophyllum*) *stokesi*, *Paleofavosites prolificus*, and *Tetradium fibratum* are listed from the upper or Selkirk member, but not from any of the underlying members of the Red River formation. *Labyrinthites monticuliporoides*, *Plasmapora lambei*, *Protochiscolithus kiaeri*, and *Syringopora conspirata* were described by Troedsson

from the northward extension of the Red River formation in northwestern Greenland.

Among these species, *Calapoecia canadensis* or its near relative *Calapoecia anticostiensis*, and *Columnaria alveolata* are widely distributed in the Richmond of North America. *Halysites gracilis* occurs in the Richmond of Wisconsin and Michigan, and a closely related form occurs in the English Head and Ellis Bay formations on Anticosti. *Protaraea magna* is known only from the southern part of Manitoba, and *Protochiscolithus kiaeri* is known only from Cape Calhoun in northwestern Greenland, but no direct comparison of these species with each other has yet been made. *Streptelasma robustum* has been identified also from Southampton Island, along the northern part of Hudson Bay. The Stony Mountain representative of *Protaraea vetusta* probably is the species *Protaraea richmondensis*, so common in the Richmond of the Ohio and upper Mississippi valleys, and not the Trenton *Protaraea vetusta;* the Dog Head representative probably also is the Richmond form. *Columnaria* (*Palaeophyllum*) *stokesi* occurs in the Richmond of Wisconsin and Michigan, and is represented by *Columnaria* (*Palaeophyllum*) *vaurealensis* in the Vaureal and Ellis Bay formations of Anticosti. *Paleofavosites prolificus* ranges throughout the Richmond and Clinton on Anticosti. *Tetradium fibratum* is represented by the closely similar *Tetradium approximatum* in the Richmond of the United States and southern Ontario. *Labyrinthites chidlensis*, the only other known species of the genus, was described from erratic material of unknown origin west of Cape Chidley at the northern end of Labrador. *Plasmopora lambei* was originally described by Schuchert from the head of Frobisher Bay; a congeneric species, *Plasmopora petalliformis*, occurs in the upper Clinton of Anticosti. The affinities of *Syringopora conspirata* are Silurian, and it belongs to that group of syringoporoids in which the tabulae are not funnel-shaped but directly transverse.

From the preceding observations it is evident that the species here listed have ample affinities with Richmond and Silurian forms. It should be noted, however, that certain species have affinities also with Mohawkian forms. The type of *Calapoecia*

canadensis, for example, was obtained near Ottawa, Canada, in the Black River. *Columnaria alveolata* is widely distributed from the Stones River and Black River to the Richmond. *Halysites gracilis* is represented by *Halysites catenularia quebecensis* Lambe in the Black River along the western shore of Lake St. John in the province of Quebec. *Protaraea vetusta* was described from the Trenton of New York, but this species may be even generically distinct from *Protaraea richmondensis*, and both species may be distinct generically from *Protaraea magna*. *Columnaria* (*Palaeophyllum*) *stokesi* apparently is related to *Columnaria erratica* Billings and *Palaeophyllum rugosum* Billings from the Black River along the western shore of Lake St. John. Specimens of *Calapoecia*, *Halysites*, and *Columnaria* (*Palaeophyllum*) found in the Black River so far all appear to be of small size and very few in number, but that does not signify that they could not have existed of larger size or in much greater numbers elsewhere, in localities not yet found. In general, most of the specimens found so far at these lower horizons have not been suitable for close study, and their accurate determination requires further study.

14. THE STRATIGRAPHIC POSITION OF THE RED RIVER FORMATION

As already noted by Troedsson, the bryozoans, brachiopods, and gasteropods of the Red River formation are of Mohawkian affinities, while the corals, and especially the cephalopods show Richmond relationships. The question, therefore, arises: To which of these divisions shall the Red River formation be assigned, to the Mohawkian or to the Richmond?

The question may be narrowed still further. Since those species in the Red River formation whose vertical distribution in the Mohawkian is most restricted show Trenton, rather than Black River relationships, is the Red River formation to be assigned to the Trenton or to the Richmond. It will be remembered that Whiteaves and Dowling placed it in the Trenton, comparing it especially with the Galena phase of the Trenton which prevails in the Upper Mississippi Valley.

However, a still further restriction is possible. If the conclusions on the preceding pages are accepted that the Red River formation is of earlier age than the Vaureal member of the Richmond and of later age than the Prosser member of the Trenton, shall it be regarded as lower Richmond, as upper Trenton, or shall it be placed in the intermediate Cincinnatian?

In deciding such questions two methods at present are in vogue, leading to very different results. If the number of species having Mohawkian affinities be compared with those having Richmond affinities, the former will have the majority, and the Red River formation will then be regarded as Mohawkian—more specifically as Trenton. On the contrary, if the first considerable invasion of species having Richmond affinities into an otherwise Mohawkian fauna be regarded as indicating contemporaneity with Richmond strata, then the Red River fauna will be regarded as of early Richmond age. It is the second method of solution which here is adopted. Hence the lower Richmond age of the Red River fauna is accepted.

However, by lower Richmond no strict parallelism with the English Head member of the Anticosti Richmond, nor with the Waynesville or Arnheim member of the Ohio Richmond is intended. Out present knowledge of the Red River fauna does not warrant such a close parallelization.

Nor is the possibility excluded that the time of deposition of the Red River fauna may have coincided with that of the deposition of some one of the Cincinnatian formations. Since many elements of the Mohawkian faunas survived during the deposition of Cincinnatian strata and reappeared during Richmond times it is evident that they must have continued their existence somewhere during Cincinnatian times; and, since the Mohawkian faunas in question are regarded as largely of northern origin, where could this survival have taken place more readily than in the north? Hence, such an intermediate surviving fauna could leave traces in the deposits of some northern area. Why not in Manitoba, and thence northward as far as northern Greenland?

This, however, would not mean that the Red River fauna would

be a Cincinnatian fauna palaeontologically. It would still be a Mohawkian fauna, but one that lived much later than those faunas stratigraphically known as Mohawkian. In other words, it would more nearly approach a Richmond fauna, the latter being made up largely of survivals of Mohawkian elements. And this is the interpretation here adopted.

15. THE ELLIS BAY FORMATION OF ANTICOSTI

Numerous survivals of an earlier fauna associated with the introduction of moderate numbers of a later fauna occur frequently in stratigraphical geology. Another illustration of such an occurrence is the Ellis Bay fauna of Anticosti, classified by Twenhofel as Ordovician, although containing such characteristic Silurian fossils as *Hallopora elegantula*, *Hallopora magnopora*, *Pachydictya crassa*, *Phaenopora ensiformis*, *Atrypa marginalis*, *Atrypina gamachiana*, *Chonetes primigenius*, *Hindella prinsiana*, *Hindella umbonata*, and *Schuchertella gamachiana*. The general aspect of this part of the fauna, as stated by Twenhofel, is Brassfield. The remainder of the fauna, however, including in fact its greater part, is of Richmondian character or origin. If correlation be based chiefly on the relative number of survivals of forms with Richmondian affinities, the Ellis Bay formation would be regarded as Ordovician, as was done by Twenhofel. However, if greater weight were given to the fact that the Ellis Bay includes the first considerable influx of species having a definite Silurian relationship, then the Ellis Bay formation would be regarded as Silurian, and its more exact correlation would be with the Brassfield.

Similar problems arise whenever it is attempted to correlate strata from widely distant localities, especially from localities in different continents. Evolution did not take place in all parts of the world simultaneously, nor at the same rate of speed, nor in the same direction. Hence, certain forms may originate in one part of the world while little change takes place elsewhere. Later the new forms may migrate, and make a sudden appearance among forms still closely similar to old types.

16. THE RINGERIKE FORMATION OF NORWAY

In the Ringerike area southwest of Oslo, in Norway, there are exposed series of rock known collectively as the Gasteropod limestone. This Gasteropod limestone is included in the *Isotelus series*, also called *Series V*, and forms the upper part of the Upper Ordovician according to the Norwegian classification of rocks. The Gasteropod limestone is of interest to Americans because it includes two genera known in America only from Richmond and Ellis Bay or Gamachian strata. These are *Billingsites* and *Apsidoceras*. *Billingsites* is represented in the Ringerike area by several species. One of these approaches *Billingsites canadensis* in size. Another is nearer *Billingsites anticostiensis* in size but is more elongated. A third is nearer *Billingsites newberryi* in size and also is relatively elongated. One specimen was found near Asker, in the Ringerike area. The *Apsidoceras* was found in the *Skien* and *Brevig* parts of the Ringerike area. The cross-section of the conch is relatively deep dorso-ventrally, and the ventro-lateral parts are more angular. The siphuncle is strongly expanded within the camerae and moniliform in outline. A form of *Cyclendoceras*, very similar to *Cyclendoceras whiteavesi* here described from the Red River formation, and also similar to a species relatively common in the Maquoketa of Iowa, is represented in the Ringerike area by several specimens. Next there is a species of cephalopod resembling *Dowlingoceras* in being relatively slender, compressed moderately in a lateral direction, with the siphuncle near one of the narrower parts of the cross-section, the ventral side. Finally, there is the genotype of *Discoceras*, namely *Discoceras antiquissimum*, and two other coiled forms apparently belonging to the same genus. The genotype has annulations which are bold ventrally and laterally as well as ventrolaterally, and the hyponomic sinus is deep and narrowly angular. In the second and more common species the annulations are weaker, disappearing laterally, and the hyponomic sinus is broader along its middle part. In the third species the annulations are reduced to swellings ventro-laterally, which disappear both ventrally and laterally. These are all large conchs, to which the relationship of the much smaller *Discoceras*

canadense from the Dog Head member of the Red River formation still is uncertain. These Ringerike cephalopods are associated with *Meristella crassa*, *Rhynchotreta cuneata*, and numerous and well developed corals which, in the Geological Museum at Oslo, are referred to the genera *Columnaria*, *Paleofavosites*, *Plasmoporella*, *Proheliolites*, *Propora*, *Protaraea*, and *Ptychophyllum*. In addition there are species referred to *Trematis*, *Maclurites*, *Isotelus*, and *Chasmops*. Here again there is an influx of Silurian forms into an area still occupied by survivals of an Ordovician fauna. Among American strata the parallelism is most direct with the Ellis Bay formation. Nothing corresponding to the typical Richmond is present. Apparently the Cincinnatian also is absent, and the Ringerike limestone rests directly on strata of Mohawkian age.

17. THE KALLHOLN FORMATION OF SWEDEN

The Leptaena limestone for a long time was placed at the top of the Ordovician of Sweden. Recently, however, Isberg and Elsa Warburg have shown that the Leptaena limestone consists of two readily distinguishable horizons, the upper of which belongs to the lower Silurian, while the lower is of middle Ordovician age. To these divisions Troedsson and Roswall have given new names, calling the lower Silurian part of the Leptaena limestone the Kallholn limestone, while its middle Ordovician part was called the Kullsberg. The latter is equivalent to the *Chasmops macrourus* limestone, regarded here as Mohawkian in age. The Kallholn, on the contrary, is approximately of the same horizon as the Ringerike limestone of Norway. It contains, moreover, two of the cephalopod genera already noted from the Ringerike limestone, namely *Billingsites* and *Apsidoceras*, both from the Dalarne area in central Sweden, northwest of Stockholm.

The specimen of *Billingsites* in the Paleontological Museum at Stockholm, was found at Kallholn. It is about 50 mm. long and 30 mm. wide, has an egg-shaped form, and a circular cross-section, faintly depressed at the aperture. There is only one conspicuously elevated dorsal saddle, and the suture of the septum

forming this saddle is very strongly recurved near midheight of the lateral side. Another specimen of *Billingsites*, in the adjoining collection of the Geological Survey of Sweden, was found at Dalbyn in the Dalarne area. The surface of its shell is faintly banded in a transverse direction, as in *Geisonoceras*, the bands or striae curving moderately downward ventrally. The *Apsidoceras* in the collections of the Geological Survey of Sweden was found at Kallholn. Its ventral side is very flat, its dorsal side is broadly rounded, its dorso-ventral diameter being approximately a little more than half of its ventro-lateral diameter. The siphuncle is approximately one-third of the dorso-ventral diameter from the ventral outline of the conch. The sutures of the septa curve downward laterally and ventrally, leaving distinct ventro-lateral saddles. The surface of the shell is striated transversely in a banded manner, similar to *Geisonoceras*. The living chamber is long.

Among the corals from the Dalarne area are *Heliolithes dubius* Schmidt, *Plasmopora conferta* Edwards-Haime, *Halysites catenularius* Linneus, *Halysites escharoides* Lamarck, *Syringophyllum organum* Linneus, and *Ptychophyllum craigense* M'Coy. Among the brachiopods are *Meristella crassa*. There is evidently a distinct influx of Silurian forms, and the Kallholn of Sweden corresponds closely to the Ringerike limestone of Norway. Both are basal Silurian rather than uppermost Ordovician.

18. THE PRESENCE OF BILLINGSITES IN ESTHONIA

The species described by Eichwald from the vicinity of Hohenholm on the island of Dagö under the name *Ascoceras deforme* unquestionably is a species of *Billingsites*. It is similar in size to *Billingsites canadensis*, and the specimen figured by Eichwald has three strongly elevated dorsal saddles. The horizon probably is the same as that of the Ringerike limestone in Norway, and the Kallholn limestone in central Sweden. The horizon evidently is either Lyckholm or Borkholm. The Borkholm is correlated by Troedsson with the Kallholn which corresponds to the Ringerike or 5b horizon of Norway. In that case the Lyckholm probably corresponds with the 5a horizon of Norway. If

that be true, the *Billingsites* from the Hohenholm area probably came from the Borkholm limestone; however, this is only a guess. Bassler does not include this species in his list of fossils from the Baltic area.

19. THE BALTIC SHIELD IN EUROPE

The Baltic shield of Europe corresponds tectonically to the Canadian shield in North America. It occupies a considerable part of northwestern Europe. Southward it extends to the southern margin of Norway, Sweden, and Finland, reaching the Baltic Sea. Eastward it reaches a line connecting lakes Ladoga and Onega with the White Sea. Northward it reaches the Arctic. It includes all but the northwestern and western part of Sweden, but of Norway it includes only the southern end. As in the Canadian shield, so also the Baltic shield is composed chiefly of pre-Cambrian rocks. The southern, western, and northwestern part of this Baltic shield is bordered by Cambrian, Ozarkian, Canadian, Ordovician, and Silurian rocks, in some areas fairly continuous, in others considerably interrupted. Eastward, the margin of the Baltic shield is covered by Devonian and Carboniferous rocks, which probably conceal earlier strata.

Westward, in Sweden and Norway, the Ordovician, Silurian, and earlier rocks have been so much metamorphosed during the period of Caledonian folding at the close of the Silurian that it has been found impossible to identify the different formations, except locally.

The axis of Caledonian folding extends in a southwest direction along the entire length of Norway and adjacent Sweden to the northern and middle parts of Great Britain and Ireland. Along the southern parts of Ireland, Wales, and southwestern England this southwestward trending axis of Caledonian folding is suddenly truncated by the Amorican axis which trends more nearly in an east and west direction. Previous to the Caledonian folding the area west of the Baltic shield was a geosyncline, receiving thick deposits of the earlier Paleozoic rocks, now metamorphosed, as already stated.

Gignoux[1] regards calcareous as well as sandy deposits as littoral, in contrast with the graptolitic shales, which are interpreted as of more pelagic origin. With this in mind he discusses the littoral facies of the Baltic shield as follows.

During Cambrian times the central part of the Baltic shield probably was not covered by the sea. At least, on all sides the Cambrian border exhibits a more littoral facies on approaching this central area. This is true especially in Scania, the Oslo area, and in the Baltic provinces south of the Gulf of Finland where the Cambrian is best known. In the Baltic provinces the shaly facies is replaced little by little by the sandy facies on approaching the central area of the Baltic shield. At the same time the succession of strata becomes incomplete at its base. In this area the sandy facies invades the entire *Olenellus* division of the Cambrian. Next, the shoreward part of the *Paradoxides* and *Olenus* shales is replaced by sandy beds containing *Obolus*. The shaly phase of the *Dictyonema flabelliforme* beds persists longer than in the underlying beds, but in certain localities even these *Dictyonema* shales become sandy and contain *Obolus*.

During the Ordovician, in a general way, more littoral calcareous facies are met as the more central parts of the Baltic shield, namely Finland, are approached. The more pelagic graptolitic beds lie farther off shore from the shield. For instance, the calcareous littoral facies is developed in Jämtland, Dalecarlia, Västergötland, Oestergötland, Oeland, Esthonia, and thence east as far as Lake Ladoga. Västergötland and Esthonia are the regions best known. Here the Tremadoc includes the *Dictyonema shales*, already discussed, overlaid by limestones or sandstones containing *Ceratopyge*. However, in Dalecarlia, in other words in that part of Scandinavia which is nearest the central part of the Baltic shield, these shaly beds are replaced by sandy layers containing *Obolus*, as already stated. These *Obolus* beds overlap the underlying beds and rest directly on the pre-Cambrian. The Arenig is represented by the *Orthoceras*

[1] Geologie Stratigraphique, Maurice Gignoux, Paris, 34–36, 72–74 (1926). Sveriges Olenid-skiffer, A. H. Westergaard, Sveriges Geologiska Undersökning, No. 18, Stockholm (1922).

limestone, which is not a deep sea deposit, notwithstanding its richness in cephalopods. The *Echinosphaerites aurantium* limestone corresponds approximately to the Llandilo, and the Caradoc is represented by the *Trinucleus* shale, and the Brachiopod shale. The pelagic graptolite shale facies, on the other hand, is developed especially well in Scania. Thence it passes into the Oslo Basin, where, by intercalation, the graptolitic shale passes into the littoral calcareous facies. Similar changes are noted in the western part of Jämtland.

During the Gotlandian, the shaly graptolitic pelagic facies prevailed in Scania. In Jämtland, the Oslo Basin, and in the vicinity of lakes Vänern and Vätern, the shaly facies alternates with the calcareous facies, the latter containing brachiopods, even corals, and in some localities crinoids. The calcareous littoral facies dominates in Dalecarlia, and especially in Gotland and Esthonia.

20. MIGRATIONS OF EARLIER PALEOZOIC FAUNAS BETWEEN EUROPE AND AMERICA

Most of the earlier Paleozoic faunas appear to have migrated between North America and Europe within the areas south of the Canadian and Baltic shields rather than north of them. The rate of this migration, however, appears to have been slow, since relatively few species are in common, and some large formations appear to be almost or altogether absent on opposite sides of the Atlantic. Some of the earlier migrations, however, skirted the northern border of the Canadian shield.

Among the fossils studied by Poulsen from northwestern Greenland, the lowest, from the Wulff River member of the Lower Cambrian, find their relationships in Labrador, Newfoundland, New Brunswick, southeastern Quebec, Vermont, New York, and eastern Massachusetts. One of its characteristic genera, *Callavia*, is known also from Shropshire in England. The equivalents of the Wulff River fauna are found also in King Oscar and Franz Joseph Fjords, in eastern Greenland, halfway between its northern and southern extremities. This distribution is of interest chiefly because it demonstrates the extension of the

Atlantic along the eastern Coast of Greenland and Labrador even in early Cambrian times.

Directly above the Wulff River formation occurs the Cape Kent formation, also of Lower Cambrian age, but related to the Mt. Whyte fauna of the northwestern United States, British Columbia, and Alberta. The Middle Cambrian fauna of the Cape Wood formation has a similar southwestern relationship, its nearest allies being in the Stephen formation of British Columbia and Alberta. The Pemmican River formation, possibly of Lower Ozarkian age, appears to be related to an undetermined horizon in Montana. All of these must have migrated along the northwestern margin of the Canadian shield. The relationships of the Lower Ozarkian Cape Frederick VII formation and of the Upper Ozarkian Cass Fjord formation are uncertain, on account of lack of diagnostic species also known elsewhere. A Middle Ozarkian fauna, somewhat older than the Cass Fjord fauna, was found by Lauge Koch in the King Oscar and Franz Joseph Fjords already mentioned, in eastern Greenland.

The Upper Ozarkian Cape Clay formation and the Upper Canadian Nunatami formation are alike in that both show western relationships with the Mississippi Valley area, especially with Missouri and Arkansas, and both also show eastern relationships: the Cape Clay formation with Upper Ozarkian strata in eastern New York and in Pennsylvania, the Nunatami formation with the Phillipsburg area of southwestern Quebec, Vermont, and Lake Champlain. In these cases migration may have taken place both along the northwestern and along the eastern margin of the Canadian shield. These cases are of interest chiefly because they suggest that the Atlantic channel still was open along the eastern side of the Canadian shield.

The Canadian is abundantly developed in Norway and Sweden, especially the lower and middle Canadian, but Troedsson adds also the *Megalaspis planilimbata* and *limbata* zones, regarding them as upper Canadian. In North America the Canadian is developed chiefly along its most eastern section, in Newfoundland, Cape Breton, New Brunswick, the Mingan Islands, the Quebec City area, in eastern New York, and thence southward as far

as Virginia. The graptolitic facies, which is most useful for purposes of correlation, is developed best in the slate belt of eastern New York and in the Quebec City area, but sufficient graptolites for purposes of correlation occur also in Cape Breton and Newfoundland. They are practically absent in the Appalachians and in the Mingan Islands. The non-graptolitic part of the Canadian fauna in America shows generic relationship with the Canadian of Europe, but few species are in common and these occur chiefly in the Canadian of Cape Breton and New Brunswick. Migration between the two continents evidently took place across the Atlantic and south of the Canadian and Baltic shields.

This makes the occurrence of *Orthoceras attavus* Brögger in Norway so much more interesting, since this species was described from the *Ceratopyge* or Middle Cambrian limestone, while an apparently identical species is fairly abundant in the Cotter or Upper Canadian of the Arkansas-Missouri area. Nothing like this Cotter fauna is known farther north in the Mississippi Valley, hence the Cotter fauna may have intruded by some path from the south, possibly having taken a more southern route across the Atlantic.

The Orthoceras limestone of the Baltic areas begins already with the *Megalaspis planilimbata* and *Megalaspis limbata* zones, which Troedsson assigns to the upper Canadian, although Lindström lists from this horizon only *Endoceras commune*. From the overlying Asaphus limestone he lists *Endoceras commune, Endoceras vaginatum, Endoceras wahlenbergi, Cyclendoceras trochcleare, Discoceras convolvens, Discoceras lamellosum,* and *Trocholites* sp. Troedsson places this Asaphus limestone in the Chazyan, and from this point upward the Chazyan includes the *Megalaspis gigas, Asaphus platyurus,* and *Illaenus centaurus* zones, closing with the *Ancistroceras* zone at the top of the Baltic representative of the Chazyan.

Many of the cephalopods characteristic of the Orthoceras limestone differ considerably from any found in America. Of the genera *Cyclolituites, Lituites, Angelinoceras, Holmiceras, Rhynchorthoceras,* and *Ancistroceras,* forming the family Lituitidae,

only one is represented in America, and that by the species *Cyclolituites americanus* Hyatt, from the Canadian of Newfoundland. The Scandinavian species of *Cyclolituites* come from the upper part of the *Orthoceras* limestone, either from the *Ancistroceras* member or from the *Illaenus centaurus* member directly beneath. None of the three species *Discoceras subcostatum*, *Discoceras lamellosum* or *Discoceras convolvans* figured by Angelin and Lindström belong to the genus *Discoceras*, having an exogastric location for the siphuncle, instead of endogastric as in that genus. The conchs are depressed dorso-ventrally, and nothing like them is known from America. The *Cyclendoceras trochleare* is different from any American species hitherto referred to that genus but resembles an undescribed Upper Canadian form from the Arkansas-Missouri area. Among the species of *Orthoceras* are several with two or three elongated grooves or short depressions approximately equally spaced around the living chamber 2 or 3 inches below its aperture. In several of the species of *Endoceras*, the line of contact between the septa and the more vertical part of the siphuncle curves upward in a manner unknown among American species. Nothing like *Bathmoceras linnarsoni* occurs in American strata. In other words, the *Orthoceras* limestone fauna of the Baltic areas has little in common with the American Chazyan. Occasionally some interesting relationship is noted, as when, for instance, *Cheirocrinus* is found in the Ottosee member of the Chazyan at Knoxville, Tennessee, and in the Aylmer member at Quebec City, while in the Baltic area it begins its range in the *Illaenus centaurus* member of the Orthoceras limestone; or when a small specimen of *Asteroblastus* is found in the Ottosee of Tennessee, while the genotype came from some unknown horizon in the Baltic area of Russia.

The Black River, Trenton, and Richmond faunas are in part absent and in part sparsely represented in Baltic areas. Troedsson correlates the *Dicranograptus clingani* beds with the lower Trenton and the *Pleurograptus linearis* beds with the top of the Utica at Holland Patent, New York. The *Dicellograptus complanatus* zone he places in the Maysville. These interpretations favor the absence of the Black River and Richmond from Baltic

areas. Evidently there was little migration across the Atlantic during Chazyan, Mohawkian, Cincinnatian, and Richmond times, at least south of a line connecting the southern outlines of the Canadian and Baltic shields.

21. BEAR ISLAND

Bear Island is located about half way between the northern end of Norway and Spitzbergen. It is interesting as being, as far as known, the most eastern exposure of certain typically American Ordovician faunas in North Atlantic waters. From the Canadian exposures on Bear Island Holtedahl listed *Calathium* cf. pannosum, *Calathium* sp., *Archaeoscyphia* cf. *minganensis*, *Maclurites* sp., *Liospira* sp., *Lophospira* sp., and *Piloceras explanator*. From the same material the present writer identified *Protocycloceras* cf. *lamarcki*, and a poorly preserved nautiloid belonging somewhere among the Tarphyceratidae. This association indicates close relationship with the Canadian of Newfoundland and eastern Canada, as pointed out by Holtedahl. The genus *Piloceras* was described originally from Durness, at the northwestern corner of Scotland, where a small but characteristic Canadian fauna occurs. This distribution suggests that the Bear Island fauna migrated northeast from the Newfoundland and adjacent Canadian areas to northern Scotland and Bear Island, and that this passage east of the Canadian shield which was open in Lower Canadian times was still open or at least again open.

Overlying the Canadian on Bear Island is another zone containing *Tetradium* cf. *syringoporoides*, bryozoa, crinoid stems, *Rafinesquina* sp., *Maclurites* sp., Kionoceras holtedahli, *Endoceras* (*Vaginoceras?*) sp., *Actinoceras tenuifilum ursinum*, *Gonioceras* cf. *occidentale*, and *Gonioceras nathorsti*. The *Tetradium* and the two species of *Gonioceras* suggest Black River, but whether more allied to the Black River of the northeastern section of America, in New York and southeastern Ontario, or to the Black River of the northern part of the Mississippi Valley can not be determined from the evidence at hand. This Black River could have reached Bear Island by either the sea southeast of the Canadian shield,

or by the sea skirting the northwestern outline of this shield, since both *Tetradium* and *Gonioceras* occur in the Cape Calhoun section in northwestern Greenland.

It is an interesting fact that although the American facies of both the Canadian and the Black River reached Bear Island, in the Arctic, and also northern Ireland, neither is known to have reached the continental part of Europe. For instance, at Khabarova, in that part of Russia which is immediately south of the Novaya Zemblya chain of islands, the fauna found is that of the *Asaphus platyurus* zone of the Orthoceras limestone of the Baltic areas of Europe, and not an American type of fauna.

22. THE ORDOVICIAN ACTINOCEROID FAUNA

During the Black River period of deposition the Actinoceroid group of cephalopods was widely distributed in the area south of the Canadian shield, being found in Minnesota, Wisconsin, the islands of northwestern Lake Huron, New York, southern Ontario and Quebec, as far east as Newfoundland. Southward it reached Kentucky and Tennessee. The Ordovician deposits of southern Manitoba and of the Lake Timiskaming area, which contain actinoceroids, are interpreted here as being of Richmond, rather than of Black River age. Strata corresponding to this southern Manitoba horizon occur on the western side of Hudson Bay, in southern Baffin Land, and as far north as the Kane Basin in northwestern Greenland. The presence of typical *Gonioceras* along the northern margin of this Kane Basin demonstrates that not only the southern Manitoba fauna, but also the typical Black River here is represented. The typical American Black River occurs also eastward from northern Greenland, on Bear Island, as already stated.

The occurrence of an abundance of Actinoceroids in North China is noted by Grabau. Here the actinoceroid horizon extends from Fengtien and Korea 800 miles southwestward to northern Hupeh, and from central Shantung 250 miles northwestward to eastern Shansi. The fauna is so distinctly similar to that of the Black River of North America that Grabau regarded the Boreal

or Arctic Sea as the center of dispersion of the Actinoceroids during Black River times.

23. THE SILURIAN IN THE AREAS SURROUNDING THE CANADIAN SHIELD

Although Silurian fossils have been collected from many localities in the American Arctic and Subarctic, little is known of their stratigraphic relationships. Nevertheless, progress has been made, and some of the data are interesting.

In the Silurian strata lying unconformably on top of the Cape Calhoun beds directly north of Cape Calhoun, along Kennedy channel, the following graptolites were found by Lauge Koch and determined by Christian Poulsen of Copenhagen: *Climacograptus scalaris, Rastrites peregrinus socialis, Monograptus lobiferus,* and *Monograptus convolutus.* This graptolite fauna corresponds to the Lower Birkhill of the Lake district of Great Britain, and in America it is equivalent approximately to the Anticostian of the Silurian section of Anticosti Island. This is the lowest Silurian known on Greenland. Higher formations are known from Kennedy Channel and Hall Basin, farther northward, and the fossils collected here by Lauge Koch are being studied at present by Poulsen, whose observations will add greatly to our knowledge of Arctic Silurian stratigraphy. No Silurian outcrops are known from the eastern coast of Greenland, nor from Labrador. Silurian areas are indicated on the maps of Newfoundland, but their stratigraphic relations are unknown. Twenhofel, however, has published recently an extensive monograph on the geology and paleontology of Anticosti in which he gives a full account of the faunas ranging from the Richmond through the Gamachian, Cataract and New York Clinton, to the possible equivalent of the Rochester and basal Lockport. In New York and in southern Ontario the Silurian ranges from the Medinan and Cataract to the top of the Cayugan. However, none of the Anticosti Silurian faunas, nor any from New York or southern Ontario, above the level of the Richmond, are known to occur anywhere on the Canadian shield.

24. SILURIAN STRATA DEPOSITED ON SOUTHWESTERN PART OF CANADIAN SHIELD

From that part of Wisconsin which lies north of the Milwaukee area, from the northern peninsula of Michigan, and from the islands in the northwestern part of Lake Huron, Silurian strata are known which differ distinctly from those farther south, in southern Wisconsin and northern Illinois. These Silurian strata have been divided by Ehlers into the following formations, listed in descending order: Racine, Manistique, Burnt Bluff, and Mayville. It will be noted that in this list the terms Racine and Mayville have long been in use. Racine is south of Milwaukee, and Mayville lies a short distance northwest of Milwaukee. Of the four formations mentioned only the Burnt Bluff and Manistique contain cephalopods in northern Michigan. Of the cephalopods in these two formations, the most interesting belong to the genera *Discosorus*, *Stokesoceras*, and *Huronia*. Of these, typical *Discosorus* is known so far only from the Clinton. In Anticosti Island, *Huronia* occurs both in the Jupiter formation and in the Chicotte formation, both of which horizons show affinities with the Manistique. Of these, the Jupiter formation is definitely Clinton, while the Chicotte may be as high as the Rochester, which by Ulrich is also placed in the Clinton. Moreover, Dr. Ulrich informed me personally that years ago he had found a genuine *Huronia* in a slab of limestone in the railroad cut at South Tunnel. At South Tunnel the only strata exposed above the Richmond are the Brassfield limestone, the Osgood clay shale, the Laurel limestone, and the Waldron clay shale. Therefore, the only source for *Huronia* at this locality was in the Laurel limestone. Finally, on a trip with Prof. Ehlers, I found several specimens of a *Palaeocyclus* resembling *rotuloides* a short distance below the *Huronia* horizon at one of the quarries on the northern peninsula of Michigan. This is an upper Clinton fossil. From these few observations it seems possible to locate the Manistique horizon somewhere beneath the Waldron shale, but above the Brassfield. *Stokesoceras* was figured by Whitfield, under the name *Discosorus conoideus*, from the *Trimerella* horizon, beneath the *Pentamerus* zone, in the Byron beds at Ash-

ford, Wisconsin, but approximately where these Byron beds belong in the New York scale is unknown. *Discosurus*, associated with *Huronia*, has been figured by Prof. A. O. Thomas from several localities in the Hopkinton dolomite of eastern Iowa. If *Huronia* there is of pre-Waldron age, then this part of the Hopkinton dolomite should be lower in horizon than those exposures at Port Byron, Illinois, which contain such a large cephalopod fauna.

In the Lake Timiskaming area, the strata identified by Hume as Lockport correspond most closely with the Manistique of the northern peninsula of Michigan. They contain *Discosorus*, *Stokesoceras*, and *Huronia*, associated with several species of *Megadiscosorus*. One of these species of *Megadiscosorus* is closely related to a form found in the Jupiter formation on Anticosti Island, which is an additional reason for regarding the Manistique as approximately equivalent to the Jupiter and Chicotte of Anticosti, and as of earlier age than the Waldron shale.

No Niagaran species of *Huronia* are known from areas farther north than Lake Timiskaming and Anticosti Island. However, two typical species of *Discosorus* were described by Dr. G. W. Lee from some unknown locality on Prince Regent Inlet. Here Parry collected Niagaran fossils from two localities, one at Port Bowen on the northwestern coast of Baffin Island, the other on the eastern coast of North Somerset, and one of these localities was the source of the specimens of *Discosorus* here mentioned. *Stokesoceras* has been described also from the Ekwan limestone of the area west of Hudson Bay, and corresponding horizons may occur on the southwestern coast of Southampton Island, north of Hudson Bay.

One of the best known sections of Silurian strata resting on the Canadian shield is that exposed west of Hudson Bay, and described in detail by Savage and VanTuyl. Here the following succession is exposed, named in descending order: Attawapiskat, Ekwan, Severn, and Port Nelson.

The Port Nelson limestone is characterized by the presence of *Virgiana decussata* (Whiteaves), originally described from Grand Rapids on the lower part of the Saskatchewan River. This horizon

is correlated by Savage and VanTuyl with the basal part of the Stonewall limestone in southern Manitoba, and with the Mayville in northern Michigan and Wisconsin.

In the Grand Rapids region of Manitoba the strata above the *Virgiana decussata* horizon contain *Pterinea occidentalis, Isochilina grandis latimarginata,* and *Leperditia hisingeri fabulina.* The Severn limestone contains the three species named and also *Camarotoechia* (?) *winiskiensis;* and the Wabi formation of the Lake Timiskaming area contains *Leperditia hisingeri fabulina* associated with *Pterinea occidentalis, Camarotoechia* (?) *winiskiensis,* and *Rhynchospira lowi.* Hence the three horizons here mentioned are regarded as approximately equivalent.

The Ekwan limestone is correlated provisionally with the Burnt Bluff and Manistique of northern Michigan, chiefly on account of the presence of *Stokesoceras ekwanense* and *Stokesoceras cylindratum* which apparently are related to *Stokesoceras engadinense* and *Stokesoceras romingeri* of the latter area.

The Attawapiskat limestone is characterized by the presence of *Phragmoceras, Pentameroceras,* and *Octameroceras,* an association suggesting approximately the same age as the Racine, but differing from the latter in containing such characteristic actinoceroids as *Armenoceras* and *Huroniella,* which do not occur in the Racine fauna, typical actinoceroids being absent there.

According to the fossils listed from Southampton Island, about all the horizons listed from the area west of Hudson Bay are represented, including the *Virgiana decussata* zone at the base, followed by the *Leperditia hisingeri, Glassia variabilis, Rhynchospira* sp., *Camarotoechia ekwanensis, Pentamerus oblongus,* and *Pycnostylus elegans* zones, the last named being characteristic of the Attawapiskat limestone.

Apparently northern Michigan, Lake Timiskaming, southern Manitoba, the area west of Hudson Bay, and Southampton Island belonged to the same faunal province throughout the Niagaran. To what extent its different elements extended farther northward is unknown. Only the species of *Discosorus* described by Dr. Lee from the shores of Prince Regent Inlet suggest a farther northward extension of any part of this fauna.

25. THE LISSATRYPA PHOCA FAUNA

The genus *Lissatrypa* was based by Twenhofel on his species *Lissatrypa atheroidea*, from the Jupiter member of the Clinton on Anticosti Island. To this genus Holtedahl has referred the species described by Salter from the Silurian of Cape Riley, at the southwestern corner of North Devon Island, and to this genus he referred also his new species *Lissatrypa scheii*, from Seal Bay on the southwestern coast of Ellesmereland. Later, after seeing much more material in the British Museum of Natural History and in the Dublin Museum, Holtedahl arrived at the opinion that his species *scheii* merely was a somewhat smaller variety of the typical *phoca*.

In his paper on the Rock Formations of Novaya Zemblya (1924, pp. 128–132), Holtedahl gives his latest views regarding the stratigraphical position of the *Lissatrypa phoca* fauna, stating: "Compared with the West-European sections . . . . the typical *Lissatrypa phoca*-horizon should probably be placed in Ludlow (Upper Salopian). We have, on one side, a marked relation to Devonian faunas, on the other, to Silurian ones." Earlier in the same paper he states: "The facts . . . . stated support my view that the horizon of the *phoca*-fauna is fairly near to the Silurian-Devonian boundary-line." In the fauna collected by Per Schei from southwestern Ellesmereland Holtedahl identified the following species characteristic of the Keyser and Decker Ferry formations at the base of the Lower Devonian of New York, New Jersey, West Virginia, and Maryland: *Cladopora rectilineata* Simpson, *Gypidula* (*Sieberella*) *coeymanensis prognostica* Maynard, *Spirifer* (*Delthyris*) *vanuxemi prognosticus* Schuchert, and *Rhynchotrema* (*Stenochisma*) *deckerense arcticum* (Holtedahl). In looking for European material comparable with *Lissatrypa phoca*, he found a species known as *Terebratula* (*Atrypa*) *prunum* (Hisinger), found in the Hemse group of Gotland, a zone in the Ludlow. By sectioning some typical specimens from Gotland he proved this species to be a *Lissatrypa*. In a similar manner he found that the species described by Buch as *Terebratula camelina*, and referred to *Gruenewaldtia* by

Tschernyschew, was a *Lissatrypa*. The latter had described his material from the Lower Devonian of the Ural mountains. Apparently the *phoca* group belongs both in the top of the Silurian and the base of the Devonian. From Fury Point and Bessels Bay a rhynchonelloid was identified as *Rhynchonella nucula* Sowerby, but Holtedahl observes that similar forms occur in the Lower Helderberg of America, for instance *Rhynchotrema transversa* Hall. A broader rhynchonelloid from Griffith Island belongs distinctly to the same type as *Rhynchotrema formosum* (Hall), and *Rhynchotrema deckerense* (Weller), both of which occur in the Keyser. The more slender specimens of the forms identified by Salter from Cornwallis Island as *Pentamerus conchidium* Dalman, resemble externally the Russian Lower Devonian species *Conchidium pseudoknighti* Tschernyschew, though the median septum of the latter probably is longer. One specimen of *Pentamerus* (*Sieberella*) *coppingeri* from Offley Island, in which no sinus is present, is very similar to *Sieberella pseudogaleata* Hall from the Lower Helderberg. Of the two large gasteropods described by Etheridge from Bessels Bay, *Acroculia haliotis* Sowerby seems to be nearly related to the Lower Helderbergian *Platyceras gebhardi* Conrad, while *Platyceras naticoides* Etheridge is similar to *Platyostoma ventricosa* Conrad. *Acervularia austini* is similar to *Acervularia gracilis* Billings from the Niagaran of Manitoulin Island, but also to *Acervularia inaequalis* Hall from the Keyser of Maryland. One of the specimens from the *phoca*-zone of Beechey Island is nearest *Cyathophyllum schucherti* Swartz from the Keyser. A coral found at Cape Hilgard has exactly the type of growth of *Syringopora tabulata* Edw. and H. The trilobite called *Encrinurus laevis* by Salter and Etheridge and *Cromus arcticus* by Houghton has a pygidium sufficiently different from that of typical *Encrinurus* to warrant the new generic name *Frammia* proposed by Holtedahl, so that its present designation becomes *Frammia arcticus*. The chief interest in this change of designation is that it suggests that the horizon of this trilobite may be of later age than typical *Encrinurus*.

These observations by Holtedahl suggest the influx into the *Lissatrypa phoca* fauna of Keyser or lowest Devonian species,

while the greater part of this fauna still consisted of survivals of Silurian forms. The question arises whether this fauna shall be called uppermost Silurian, on account of the greater percentage of Silurian species present, or lowermost Devonian, on account of the introduction of species elsewhere regarded as characteristic Lower Devonian forms.

The same problem arises often in modern paleontological research. Similar cases have been discussed on the earlier pages of this paper, in connection with the determination of the age of the Red River formation, and that of the Ellis Bay formation. It arose when the determination of the age of the Girardeau member of the Alexandrian was in question. If the evidence presented by Holtedahl concerning the Keyser relationship of the *phoca* fauna be accepted, then this *phoca* fauna should be regarded as contemporaneous with the latter, and should be assigned to the basal Devonian, if the Keyser fauna is basal Devonian.

26. LIST OF SPECIES OCCURRING IN THE LISSATRYPA PHOCA FAUNA

Lissatrypa phoca was described originally from Cape Riley, at the southwestern corner of North Devon Island. It occurs in a band extending from northwestern Greenland to Boothia peninsula, in a NNE to SSW direction. It has been recorded from Cape Tyson, north of Petermann Fjord in northwestern Greenland; Bessels Bay, farther south in Greenland; Dobbin Bay, west of Kane Basin, on the eastern coast of Ellesmereland; Cape Riley, on the southwest corner of North Devon Island; Beechey Island, south of Cape Riley; Cornwallis Island, west of the southwestern part of North Devon; Griffith Island, southwest of the latter; near Port Bowen, east of Prince Regent Inlet, at the northwestern corner of Baffin Island; at Garnier Bay, on the north coast of North Somerset; Fury Point, on the southeast corner of North Somerset; Cape Farrand, on the northeast side of Boothia Peninsula; and also along the western coast of this peninsula.

The following list includes those species which are recorded at the preceding localities, presumably from the *Lissatrypa phoca* horizon. Some of these possibly may have come from im-

mediately overlying or underlying horizons, but there is no way of determining this fact from the published statements. The names of the individual localities at which the species named were found is indicated in abbreviated form. No attempt at corrections of the original nomenclature here is attempted, though some of the preceding remarks, based on the critical studies of Holtedahl, are illuminative.

Actinostroma franklinense, Beechy.
Clathrodictyon cystosum, Bessels, Beechy.
Stromatopora concentrica (constellata), Bessels, Fury.
Acervularia (Strephodes, Clisiophyllum) austini, Beechy, Cornwallis, Griffith, Fury.
Alveolites (Cladopora) articus, Beechy.
Amplexus (Calophyllum) phragmoceras, Beechy, Griffith.
Boreaster lowi, Beechy.
Columnaria (Favistella) franklini, Dobbin, Riley, Beechy, Cornwallis, Fury, west side of Boothia.
Columnaria (Beaumontia) sutherlandi, Bessels, Beechy, Garnier.
Chonophyllum magnificum, Dobbin.
Cyathophyllum articulatum, Dobbin, Beechy.
Cyathophyllum (Diphyphyllum?) caespitosum, Beechy, Fury.
Cyathophyllum helianthoides, Garnier, Fury.
Cyathophyllum (Strephodes) pickthorni, Riley, Beechy, Cornwallis, Griffith.
Diphyphyllum sp., Dobbin.
Favistella (Columnaria?) reticulata, Riley.
Favosites gothlandicus, Bessels, Dobbin, Beechy, Fury, Farrand.
Favosites sp., Riley.
Halysites catenulatus, Dobbin.
Halysites parryi, Prince Regent Inlet.
Heliolites megastoma, Garnier.
Heliolites porosa, Garnier.
Pachypora sp., Beechy, Griffith.
Palaeophyllum sp., Beechy, Griffith.
Paleofavosites asper (Favosites alveolaris), Beechy.
Petraia bina, Fury.
Strephodes (Acervularia?) salteri, Riley, Beechy.
Syringopora geniculata, Cornwallis, Griffith.
Syringopora parallela, Dobbin, Riley, Cornwallis, Griffith.
Zaphrentis offleyensis, Bessels.
Zaphrentis prolifica, Dobbin.
Chaetetes arcticus, Beechy.
Chaetetes lycoperdon, Fury.
Atrypa mansoni, Bessels.
Atrypa marginalis, Dobbin, Seal, Bessels.
Atrypa, ribbed, Beechy, Griffith, Farrand.

Atrypa reticularis, Tyson, Bessels, Dobbin, Seal, Griffith, Garnier.
Chonetes sp., Griffith.
Conchidium biloculare, Griffith, Cornwallis.
Conchidium knighti, Griffith.
Rhynchonella nucula, Bessels.
Spirifer crispus, Cornwallis.
Strophomena donetti, Griffith.
Strophonella sp., Cornwallis.
Loxonema rossi, Beechy, Griffith, Farrand, west side of Boothia.
Loxonema salteri, Cornwallis, west side of Boothia.
"Maclurea" arctica, Fury.
Platyceras (Acroculia) haliotis, Bessels, Dobbin.
Platyceras naticoides, Bessels.
Straparollus sp., Beechy.
Cardiola salteri, Cornwallis.
Tellinomya sp., Beechy.
Armenoceras coppingeri, Dobbin.
Armenoceras donetti, Cornwallis.
Armenoceras ommanyi, Cornwallis.
Armenoceras rotulatum, Bessels.
Armenoceras sphaeroidale, Dobbin (?).
Armenoceras sp., Offley.
Kionoceras myrice, Offley.
"Lituites" sp., Cornwallis.
Offleyoceras arcticum, Offley.
Orthoceras griffithi, Cornwallis, Griffith.
Sactoceras sp., Cornwallis, Griffith.
Beyrichia clathrata, Beechy.
Beyrichia plagosa, Beechy.
Leperditia arctica, Cornwallis, Seal.
Leperditia gibbera, Beechy.
Leperditia hisingeri, Beechy.
Primitia muta, Beechy.
Primitia rugulifera, Beechy.
Primitia sigillata, Beechy.
Calymene sp., Dobbin.
Frammia (Encrinurus laevis, Cromus arcticus) arcticus, Cornwallis, Griffith, Garnier.
Goldius flabellifer, Bessels.

In addition, the following species, coming from localities from which *Lissatrypa phoca* has not been reported so far, may come from the same horizon, judging from the associated fossils, which are known to occur in the *phoca* fauna elsewhere.

Amplexus feildeni, Offley Island.
Naos (Ptychophyllum) pagoda, Disaster Bay, Melville Island.

Strombodes (Arachnophyllum) richardsoni, Cape Hilgard, Point Eden, Baring Bay.
Chonetes striatellus, Cape Louis Napoleon.
Conchidium arcticum, Baadkap on North Devon Island.
Gypidula (Pentamerus) coppingeri, Offley Island.
Stropheodonta feildeni, Cape Hilgard.
Strophonella euglypha, Cape Hilgard, Cape Louis Napoleon, North Devon.
Euomphalopterus (Helicotoma) naresi, Offley Island.
Loxonema mcclintocki, Port Leopold.
Murchisonia latifasciata, Offley Island.

27. DISTRIBUTION AND ORIGIN OF LISSATRYPA PHOCA FAUNA

The *Lissatrypa phoca* fauna occurs chiefly in that part of Arctic America which extends from northwestern Greenland to Boothia Peninsula, west of the northern part of Baffin Land. At no point is this fauna known to be in contact with the northward extension of the Niagaran faunas characteristic of the northern peninsula of Michigan, Lake Timiskaming, southern Manitoba, the area west of Hudson Bay, and Southampton Island. There is a possibility that if the locality on Prince Regent Inlet from which Dr. Lee described two species of *Discosorus* could be rediscovered, that this would assist in giving some idea as to the stratigraphical relationships of these two faunas, aside from what can be determined by a study of the faunas themselves.

No trace of this fauna occurs on any part of the Canadian shield south of Boothia Peninsula. Apparently it entered the northern area of the Canadian shield from some North Atlantic source. The nearest strata of approximately the same age are those found in the Monroan of Michigan, southern Ontario, and Ohio, but the affinities of the *Lissatrypa phoca* fauna are with the Keyser and related faunas of New York, New Jersey, West Virginia, and Maryland, rather than with the Monroan.

However, the Monroan is similar to the *Lissatrypa phoca* fauna at least in one respect: it presents species with lower Devonian affinities along others which suggest survivals of a Silurian fauna.

28. FAUNAL PROVINCES IN ORDOVICIAN AND SILURIAN TIMES IN AMERICAN ARCTIC AND SUBARCTIC REGIONS

As is well known, the Richmond contains many survivals of Black River and Trenton species not known in the intermediate

Cincinnatian faunas. During Cincinnatian times they must have continued in existence elsewhere. The question is, Where? Since the general distribution of those Black River and Trenton species which survive, with moderate modifications, in Richmond times is northern it was natural to expect this survival to have taken place in northern waters. This might have been in the north Atlantic or in the Arctic.

With these ideas in mind the writer expected to find abundant evidence of the presence of Black River and Trenton fauna in American Subarctic and Arctic areas. Confirmation of these ideas appeared to be given by the cephalopods studied from the King William Land—Boothia peninsula area and from the drift material found at Port Burwell, west of Cape Chidley in Labrador. The cephalopods from both areas were interpreted as of Black River age, especially on account of coiled forms referred to the genera *Plectoceras* and *Eurystomites*. Moreover, *Gonioceras occidentale* is listed from the former of these two areas. The coiled cephalopods from the Cape Chidley area appeared more closely related to those of the upper Mississippi Valley than to those of New York and southwestern Quebec.

Confirmation appeared to be given also by the Ordovician strata exposed in southern Manitoba, in the Lake Timiskaming area, and in the region southwest of Hudson Bay, all of which formerly were regarded as Mohawkian. However, if the Ordovician strata in the areas just named now are to be regarded as of Richmond affinities, as argued on the preceding pages, then typical Mohawkian formations must be acknowledged to be relatively scarce in the American Arctic. The only areas in which they appear to occur, as far as known at present, is around the borders of the Kane Basin, especially at Cape Calhoun, where typical *Gonioceras* is known.

In a similar manner, the Stony Mountain formation of southern Manitoba was found to have a fauna very similar to that of the Vaureal member of the Richmond in Anticosti. This is a very long distance in an east and west direction, but relatively little of this resemblance remains in the fauna of the Shamattawa

limestone west of Hudson Bay and no representatives whatever occur in true Arctic areas.

Instead there are in Arctic areas only the representatives of the Red River fauna, extending from northwestern Greenland as far southwest as southern Manitoba. Corresponding strata of Arctic origin appear to extend across Montana, Idaho, and Colorado, as far as northern Texas. The latter, however, do not contain the characteristic cephalopod fauna of the Red River formation, so that this Red River formation can be said to be located north of the typical Ohio-Indiana Richmond, occupying a distinct basin. The northern limits of this Ohio-Indiana Richmond appear to be not much farther north than the southern part of Georgian Bay and the northwestern part of Lake Huron, where it is represented in the Maitoulin Island area.

How to account for the long extension of the Arctic type of Richmond into the Rocky Mountain area, as far southward as Texas, is another question. Possibly there were oceaning currents trending in a general way southward across this area, carrying traces of this Arctic Richmond fauna southward, but giving little evidence of any migrations from the south toward the north.

In 1900 Stuart Weller published an account of the Crinoidea of the Chicago area in which he presented a paleogeographic map in which the Silurian of the interior parts of America had but one outlet to the sea and that was by way of the Arctic. A second map showed the hypothetical distribution of land and sea of the polar areas of America and Europe, indicating a possible route of travel of crinoid faunas between the Baltic areas of Europe and the Silurian areas of northern Illinois and southern Wisconsin. Practically all of the crinoids studied by Weller belonged to the Racine formation. This Racine crinoid fauna, accompanied by cystids characteristic of the same fauna, and numerous other fossils evidently from the same horizon, is typically developed in the Cedarville formation of southwestern Ohio. Faunas of the Racine facies, but containing more cephalopods than crinoids or cystids, occur in northwestern Ohio and thence northeastward in the peninsula between lakes Huron and Erie. Less typically,

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this fauna is indicated by cephalopods and other fossils in the Lockport and Guelph of New York. A cephalopod fauna closely related to the Racine reaches the Mississippi River at Port Byron, in northwestern Illinois.

With this large east and west extension of the Racine fauna in mind, and taking consideration also of the theory by Weller as to the Arctic route of migration of Silurian fossils during Gotlandian times, the writer began to search for evidences of faunas with Racine affinities in the American Subarctic and Arctic; however, it must be admitted, with very little success. On the contrary, north of the area within which the Racine fauna is developed there was apparently a distinct type of Silurian, including the Silurian of the northern half of Wisconsin, the northern peninsula of Michigan, the area surrounding Lake Timiskaming, the area west of Hudson Bay, and that occupied by Southampton Island. A fauna distinct from the latter, the *phoca* fauna, occupies the more northern part of the Canadian shield, from Boothia Peninsula northward to the northwestern part of Greenland. Both of these faunas are typically American, rather than European, in their nearest affinities.

Therefore, the path along which Silurian faunas migrated between Europe and the Racine area of the interior of America is not determined so readily as once supposed. At present, this path appears to have been south of both the Canadian and Paltic shields.

Last summer the writer had the opportunity of examining the great wealth of cephalopod material belonging to the Paleontological Museum at Stockholm, in Sweden, and he was impressed by the abundance of gomphoceroid, phragmoceroid, trochoceroid, and other material found in the Gotlandian of Sweden which shows close affinities to forms known also in the Silurian of Bohemia. Among these are such peculiar forms as *Pentameroceras mirum* and *Inversoceras perversum*, both of which occur in the Silurian of Bohemia and also in the Racine of Wisconsin. The fact is that to a student of cephalopods the Racine is largely a Bohemian fauna. However, crinoids play but a small part in the Silurian of Bohemia, while they are an important part of the

Silurian of Gotland. Hence the crinoidal and cephalopod elements of the Racine could much more readily be derived from the Baltic areas than from the Bohemian. However, migration appears to have taken place south of the Baltic shield, rather than east and north of it.

Finally, a study of the Silurian faunas so far discovered in the areas north of Russia and Siberia is convincing in showing that these faunas have their affinities with European, rather than with American sources. In the present stage of our knowledge of these faunas their affinities are definitely with those from the Baltic areas. Apparently migration was possible in both directions, northward along the eastern side of the Baltic shield, and westward along its southern side. But these two migrations differed in their elements, and it is the first of these routes of migrations which brought the Silurian faunas to northern Russia and Siberia, while the second brought the Racine fauna to the interior of North America.

It is very evident that the Siberian Silurian faunas have been studied so far almost altogether in the light of what is known of the Baltic Silurian. Eventually, when the Siberian faunas become much better known, it is probable that considerable differences, now not recognized, will turn up. There will then be recognized an Irkutsk basin fauna quite distinct from that of the Baltic.

29. CLIMATIC CONDITIONS IN ARCTIC AREAS DURING EARLY PALEOZOIC TIMES

The most northern locality from which fossils from the Red River formation are known in any abundance is Cape Calhoun, on the northwestern coast of Greenland. No comparable data from any corresponding northern area of typical Silurian rocks are at our service, since the studies of Dr. Christian Poulsen have not yet been published. On that account I have used the list here published of fossils assumed to belong to the *Lissatrypa phoca* fauna, since they occur at localities from which *Lissatrypa phoca* has been recorded. In the list of fossils from Cape Calhoun, all of those recorded by Troedsson from that locality,

regardless of the formations to which they have been assigned, whether given specific names or not, are here summarized. The object is to get some idea of Arctic faunas in early Paleozoic times. As already noted, the Red River fauna is regarded here as belonging low in the Richmond, while the *Lissatrypa fauna* appears to have its nearest relatives in the Keyser, which at present is placed at the base of the Lower Devonian.

	NUMBER OF SPECIES		PERCENTAGE OF TOTAL	
	Red River fauna	Phoca fauna	Red River fauna	Phoca fauna
Ostracods	2	8	1	11
Trilobites	47	2	23	3
Cephalopods	66	11	32	15
Gasteropods	22	6	11	8
Pelecypods	1	2	1	3
Brachiopods	22	10	11	14
Bryozoans	16	2	5	3
Echinoderms	3		1	
Hydrozoans		3		4
Corals	23	28	11	39
Sponges	2		1	
Calcareous Algae	4		2	

In these lists it will be noted that in the Red River fauna the cephalopods dominate, that the trilobites come next, and that the gasteropods, brachiopods, and corals follow, forming equal percentages of the total fauna. Ostracods, pelecypods, echinoderms, and sponges are represented by only 1, 2, or 3 species each. In the *Lissatrypa phoca* fauna, on the contrary, the corals come first, followed by the cephalopods, brachiopods, ostracods, and gasteropods, in the order named, while those of scanty representation are the hydrozoans, trilobites, pelecypods, and bryozoans, no echinoderms or sponges being recorded at all.

In studying the early Paleozoic faunas of Arctic areas two things have attracted the attention of all observers, one of these is the abundance of corals, the other is the scarcity of pelecypods. Forty years ago Etheridge commented on these facts. The abundance of corals has been used by many observers as an evidence of warm climates during Ordovician and Silurian times.

Troedsson states that "The deposition of lime in organisms is highly facilitated by high temperature. This is a physiological law manifested by almost all classes of marine invertebrates in present time. As a physiological law it must be as old as organisms, and its manifestation in the Ordovician Arctic waters proves tropical or at least sub-tropical conditions at what is now the Arctic Pole. This indicates that the Poles and the Equator (or the continents) have moved considerably. If the Ordovician Equator extended over Hudson Bay and North China, which there are some reasons to believe, the Baltic area was far outside of this region. . . . . This interpretation of a less warm climate in the Baltic Ordovician is in accordance with the statement by Holtedahl that the tillites of northernmost Norway are of Ordovician age."[2]

Troedsson refers also to the large size of the cephalopods and the wide-spread occurrence of calcareous deposits largely built up of organic material as evidence of warm conditions. The only observations by the present writer which possibly may have some bearing on the question of climate are concerned with cephalopods. In a recent study of the cephalopods from the Red River formation of southern Manitoba he was struck with the large number of species, especially among the cyrtoceroids and nautiloids, in which the shell was of remarkable thickness. Similar observations had been made previously on the nautiloids studied from the drift material at Port Burwell, west of Cape Chidley, in northern Labrador. The latter were regarded as of Black River age, with affinities to the Black River of the northern Mississippi area. The Red River formation of southern Manitoba extends northward as far as the Cape Calhoun area, whose fossils were studied by Troedsson. When I studied these fossils from Cape Calhoun, with the kind permission of Dr. Troedsson, it did not occur to me to make any special observations on the thickness of the shell presented by species closely related to those found in southern Manitoba, but there is a possibility that

[2] On the Middle and Upper Ordovician Faunas of Northern Greenland, pt. 2, Gustaf Troedsson, 187–188 (1928).

a study of the thickness of the shells of cephalopods from various Ordovician and Silurian horizons might lead to some results having a bearing on early Paleozoic climates.

The assumption that corals indicate warm climates is based largely on the present distribution of corals, though Dr. Troedsson called to my attention the fact that corals are now living along the northwestern coast of Norway, so that they are living at least farther north than climates of a tropical nature. One of the chief difficulties in drawing conclusions from the presence of corals in Ordovician and Silurian times is that the genera then present have no close relationship with those now living. Early Paleozoic corals, therefore, may have been adapted to much colder climates than those now occurring where corals are abundant.

The fact that animals usually supposed to be adapted chiefly to warm climates have succeeded in adapting themselves to much colder climates is too well known to require comment. However, it might be well for those too insistent on arguing from present distribution of certain types of animals to former climates in areas where their relatives are found to bear these cases of adaptation in mind. To mention only a few with which everyone is familiar, the elephant and the rhinoceros evidently thrived during the glacial conditions in northern Siberia, considering the abundance of their remains in Siberian areas. Moreover, the Bactrian camel is most vigorous in cold weather, as is asserted by all explorers who have been obliged to use this animal in their journeys across the snow-clad mountains of Turkestan, and neighboring countries.

Unfortunately too little is known of the effect of climatic conditions on marine faunas. Even specialists who have devoted many years to the study of northern marine faunas have rarely attempted to bring together into a single publication sufficient facts to warrant generalizations. Probably there is no greater need at the present time than a study of the relationship of marine faunas of the world to climate, on a scale commensurate with the present study of sedimentation, inaugurated by Twenhofel and others.

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PLATE II

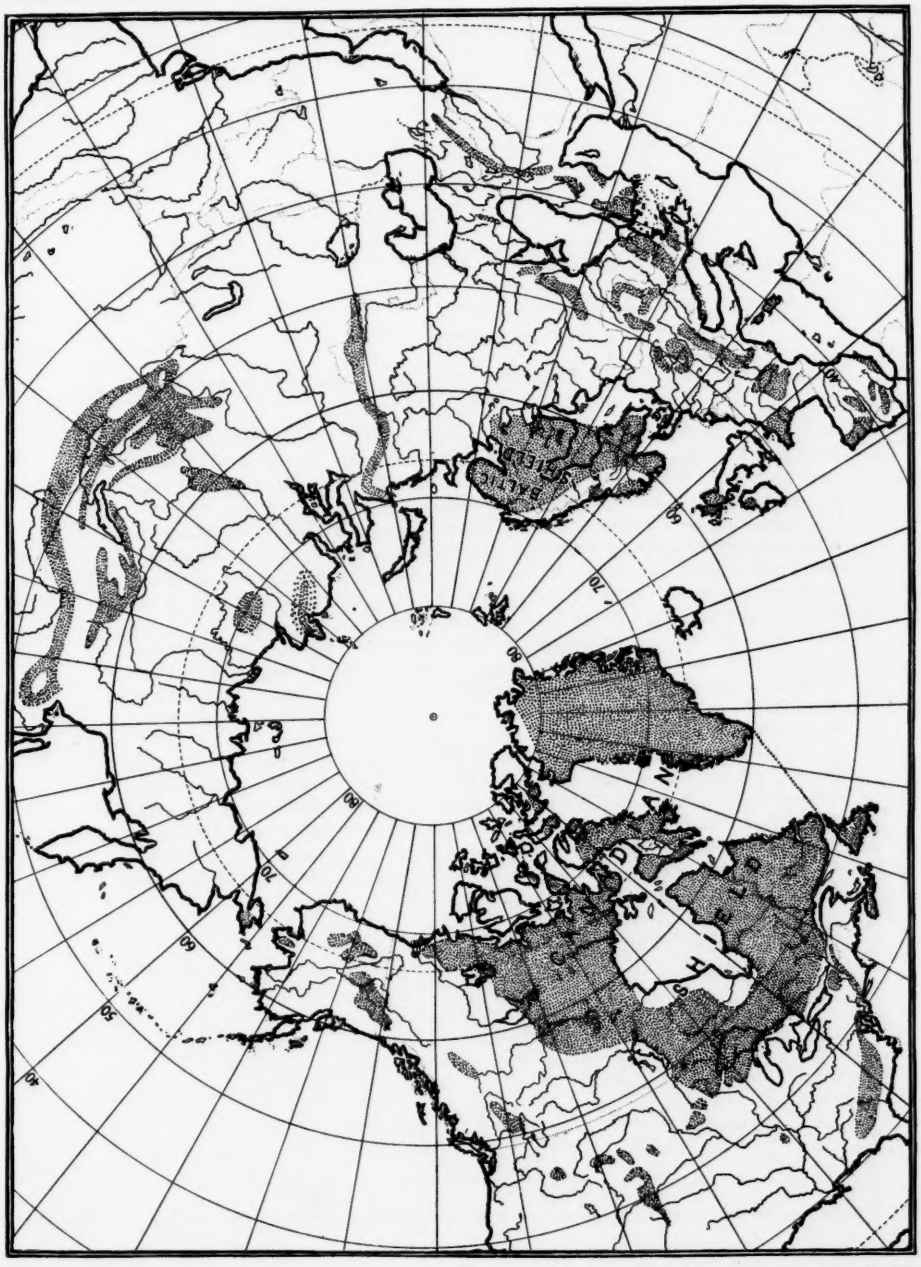
The Canadian and Baltic Shields

West of the Canadian shield lie the broad plains at present drained by the Mackenzie River. Southward lies the area drained by the Mississippi River. From the pre-Cambrian of the Atlantic states it is separated by the area drained by the St. Lawrence. East of Greenland is the North Atlantic. Pre-Cambrian rocks dominate large areas in the eastern half of the American Arctic Archipelago.

The Baltic shield includes Sweden, the southern tip of Norway, Finland, and the adjacent part of northwestern Russia. West of the Baltic shield lies the area of Caledonian faulting extending lengthwise through Norway to Scotland, northern Wales and Ireland. In pre-Caledonian times this area was a geosyncline. South of the Baltic shield is a broad area of depression extending from eastern England, Belgium, Holland, and Denmark, across northern Germany, Poland, Lithuania, Latvia, and Esthonia, into Russia. This area of depression separates the Baltic shield from the various pre-Cambrian areas exposed in the various mountain systems extending from France and Spain across southern Europe to the Balkan States and Asiatic Turkey. East of the Baltic shield lie the broad plains of northern Russia.

The Baikal shield, much folded, extends east and west along the northern part of Mongolia and the adjacent part of southern Siberia. Northward lies the Irkutsk basin, and Angara land.

These are the dominating features of the more northern lands during early Paleozoic times.



AUG. F. FOERSTE

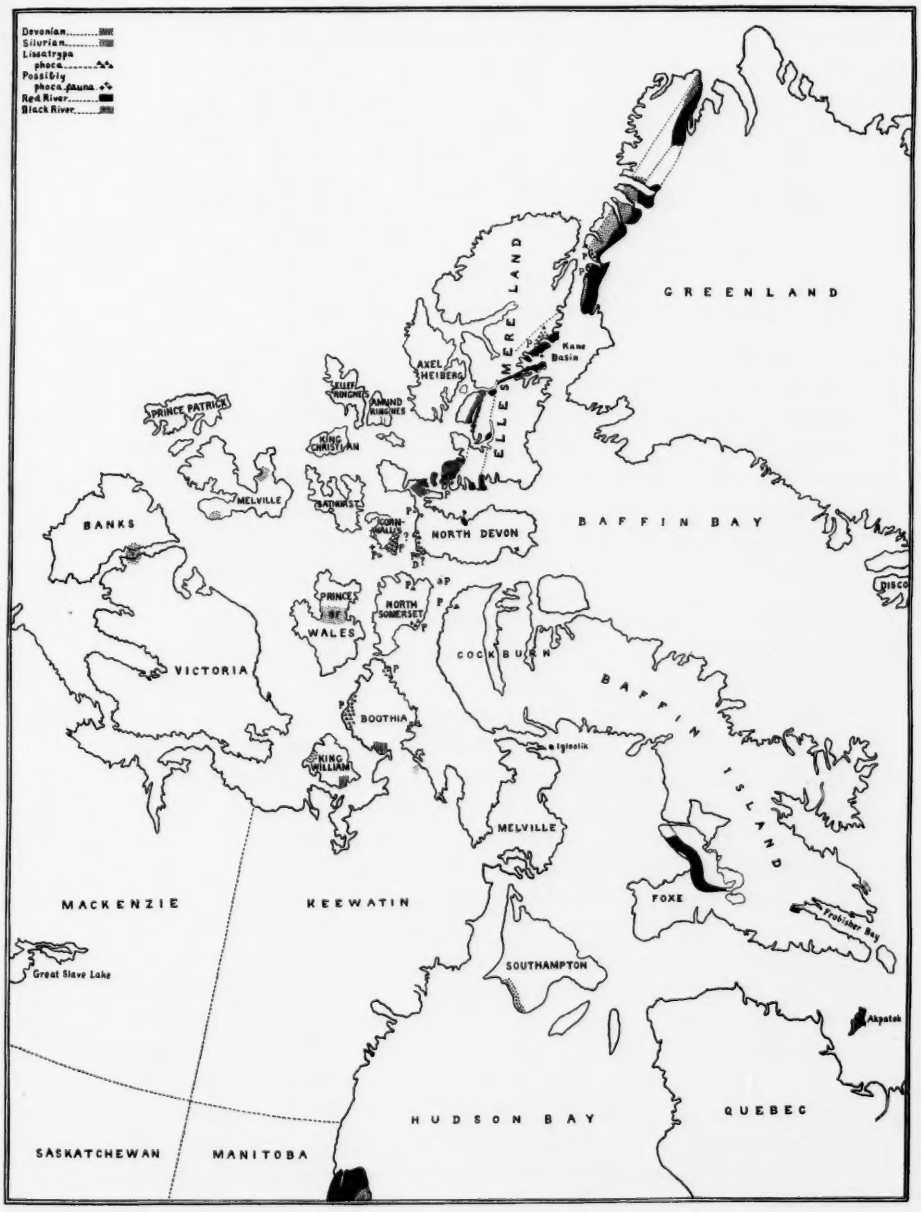
AMERICAN ARCTIC AND SUBARCTIC REGIONS

PLATE III

DISTRIBUTION OF ORDOVICIAN, SILURIAN AND DEVONIAN STRATA IN THE AMERICAN ARCTIC AND SUBARCTIC

Faunas regarded as of Black River age occur in the King William Land—Boothia Peninsula area, on Apatok Island, and directly east of Apatok Island near Cape Chidley in the northern part of Labrador. The Ordovician exposures at the head of Frobisher Bay are not indicated.

The Red River formation, characteristically exposed in southern Manitoba, occurs also southwest of Hudson Bay, northeast of Foxe Land on Baffin Island, on Igloolik Island, and on both sides of Kane Basin, in Ellesmereland and northwestern Greenland. It probably occurs also in southern Ellesmereland, the northern part of North Devon, and the North Arm of Great Slave Lake. The *Lissatrypa phoca* fauna, indicated both by the letter P and by minute triangles, extends along a relatively narrow area from northwestern Greenland to Boothia peninsula. Small crosses on the western part of North Devon, southwest of Cornwallis Island, and between Banks and Victoria Islands indicate localities at which *Lissatrypa phoca* is unknown, but at which the fauna which accompanies that species is present. The small dots on Melville, Prince of Wales, and King William Islands, and also on northwestern Greenland, indicate areas where the fauna is Silurian in character but its exact relationships are unknown. The Silurian faunas found along the southwestern margins of Southampton Island have their nearest relationships in those of the area southwest of Hudson Bay and in the southern part of Manitoba. Devonian is indicated by diagonal lines on Ellesmereland and North Devon.



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AMERICAN ARCTIC AND SUBARCTIC REGIONS

LOCATION FACTORS IN THE IRON AND STEEL INDUSTRY OF CLEVELAND, OHIO

CHARLES LANGDON WHITE

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A study of the American iron and steel industry reveals the fact that all *major districts* have grown and prospered primarily because they were located with careful regard to the economies of manufacture and distribution. They lie near the coal as does Pittsburgh, near the ore as does Duluth, near both coal and ore as does Birmingham, or somewhere along the route of most economical transportation, where the two may meet, as does Cleveland; *and they lie near important markets.*

CLEVELAND'S LOCATION AND TYPOGRAPHY

Physiographically Cleveland lies in the narrow Lake Plain section of the Interior Plains province. It is on the shore of Lake Erie at the debouchure of the Cuyahoga River, 560 miles by rail from New York and 340 from Chicago.

While Fairport, Sandusky, and Toledo all have better natural harbors, they are handicapped by being separated from the Pennsylvania coal fields by such barriers as rugged relief, swamps, or distance. Moreover, the railways leading down to the lake from the coal fields reach Cleveland by exceptionally easy grades and by very direct routes.

At the mouth of the Cuyahoga is the biggest cut in the shale cliffs which hug the southern periphery of the lake from Dunkirk, New York, to the Vermilion River in Ohio. This is the only appreciable section along this great sweep of shore where the steel rail meets the water's edge with comparative ease (fig. 1).

Cleveland sits in an amphitheater, whose center aisle is the Cuyahoga River (fig. 2). This aisle, locally dubbed "the flats," is about 100 feet below the floor of the amphitheater and divides

the city in twain. An old bayou, near the mouth of the river, has been dredged and is well adapted to ore-handling and shipbuilding.

The salient geographic facts connected with the lake front and the river are discussed in detail in ensuing pages.

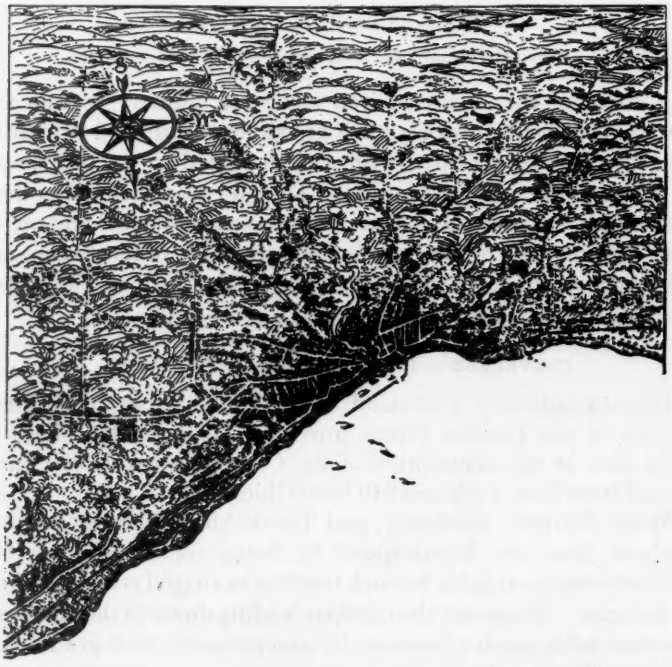


Fig. 1. Sketch of Cleveland's strategic location on Lake Erie at the mouth of the Cuyahoga River. Here the trinity—iron ore, coal, and limestone—meet naturally and scientifically and are converted economically into iron and steel. Here too, are many important steel-consuming industries, which have been largely responsible for the city's becoming one of the world's greatest manufacturing centers. (From *The Clevelander*.)

MAJOR LOCATION FACTORS IN CLEVELAND'S METALLURGICAL INDUSTRY

Cleveland has a scientific general location for iron and steel manufacture, because it is located at the intersection of two

heavy lines of traffic. It is the northern terminus of the principal lowland route connecting the coal fields of Pennsylvania with Lake Erie, and it occupies a strategic lacustrine location, which insures economical water transportation on ore and limestone—

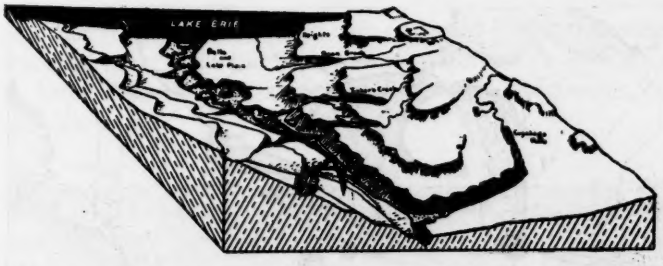


Fig. 2. Physiographic diagram of the Cleveland area. The amphitheater, which characterizes the site of Cleveland, is bisected by the Cuyahoga River along which all the early commercial and industrial activity was focused. (From *A Geography of Cleveland,* published by the Union Trust Company.)

TABLE 1*

Approximate raw material assembly costs at Cleveland, Pittsburgh, and Youngstown

DISTRICT	COKE (2,050 LBS.)	ORE (4,000 LBS.)	FLUX (900 LBS.)	TOTAL
Cleveland	$2.24†	$3.23	$.20	$5.67
Pittsburgh	.28 (100% water-borne)†	5.39‡	.35	6.02
Youngstown	1.78†	4.81‡	.22	6.81

* These valuable data were supplied by the Cleveland Chamber of Commerce.

† 70 per cent of the transportation costs chargeable to coke is included in the cost of assembling raw materials for pig iron and 30 per cent is borne by the by-products.

‡ In the cases of Pittsburgh and Youngstown, 80 per cent of the transportation cost of ore is calculable on the basis of direct shipments and 20 per cent on the basis of dock ore.

two of the trinity of basic raw materials for iron-making. Moreover, it is excellently situated with reference to the markets of the Northern Interior—especially the Michigan automotive industry.

The significance of Cleveland's *general location* is set forth in table 1, which shows that its assembly costs are notably less than

those of its two chief competitors, Pittsburgh and Youngstown. Moreover, they are less than those of all districts utilizing Lake Superior ore. In the whole western hemisphere, only Birmingham has lower assembly costs.

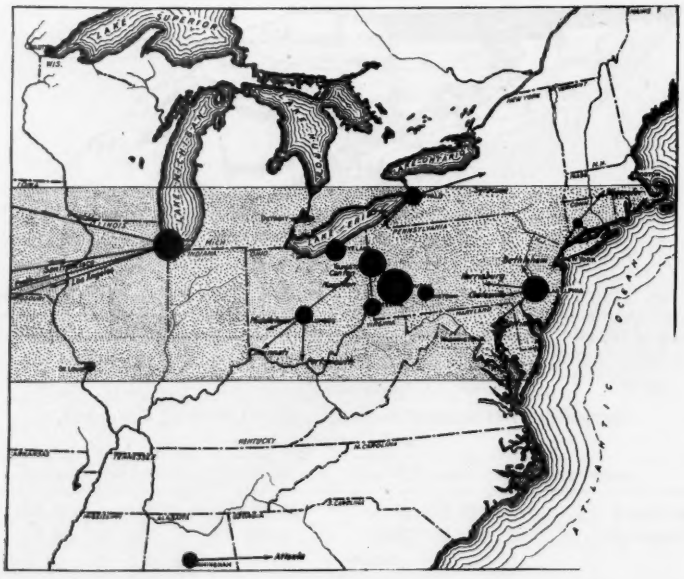


Fig. 3. Distribution of iron and steel districts in the eastern half of the United States as grouped by the Federal Trade Commission in the Pittsburgh basing case. The areas of the circles are proportional to the ingot capacity of the districts. The arrows and accompanying names of cities are to indicate where scattered plants belong in the districting scheme. The area for Chicago is proportional to the ingot capacity of that district, excluding plants in Colorado and on the Pacific Coast, which are indicated by arrows. For the time covered, the end of 1922, Detroit's capacity was too small to show proportionally. The shaded area, representing the zone of densest steel consumption, lucidly portrays Cleveland's strategic industrial and commercial location. (Data from *The Iron Age* and *The Iron Trade Review.*)

In consideration of Cleveland's early start and its highly favorable site, one would expect it to rank very near the top among American districts in steel capacity and production. Yet statistics show that on the basis of steel ingot capacity, it ranks not first but fifth, being surpassed by Pittsburgh, Chicago, Youngs-

town, and Philadelphia (fig. 3).[1] So anomalous a situation merits a geographic analysis.

CLEVELAND'S IRON AND STEEL INDUSTRY IN RELATION TO THE CITY'S SPECIFIC SITE

An analysis of the Cleveland iron and steel industry should be concerned more with the little known peculiarities of the city's site than with the well-known and obvious advantages of its general location.

CLEVELAND'S HARBORS

Cleveland has two harbors—one on the lake front, devoted to commerce, the other on the river, to industry.

The Outer Harbor.—Cleveland's lake frontage totals eleven and two-tenths miles, one-half of which is protected by a breakwater (Plate IV, fig. 4). The depth of the water here exceeds 20 feet and the distance from the breakwater to the wharves is sufficient to accommodate easily the largest freighters plying the lakes. The west basin is equipped with ore-handling machinery only, whereas the east basin is equipped with car dumps, a concrete shipbuilding plant, a lumber dock, a government wharf, and passenger steamship piers.

In the following respects, Cleveland surpasses commercially the keepers of Lake Erie's east and west portals—Buffalo and Toledo: (1) it lies closer to Pennsylvania's coal fields, (2) it is open almost a month longer than Buffalo, (3) it is not blocked by ice floes at the beginning and end of winter, and (4) it is troubled less with fluctuating depth.[2]

Outer Harbor's Ore Receipts Destined for Transshipment.—Cleveland ranks first among lower lake ports in ore receipts. In 1928 it received 9,375,764 tons; it was trailed by Conneaut and Ashtabula with 8,437,401 and 6,376,035 tons respectively.[3]

[1] The Philadelphia District includes Bethlehem, Coatesville, Harrisburg, and Sparrows Point, a grouping used by the Federal Trade Commission in the Pittsburgh basing case.

[2] Strong, Helen M., "Cleveland: A City of Contacts," *Economic Geography*, Vol. I, 200.

[3] Tinker, W. L., Secretary, The Lake Superior Iron Ore Association. Personal Communication.

Mountains of red hematite are dumped here for transshipment to Youngstown, Pittsburgh, Sharon, Steubenville, Ironton, Johnstown, and other points in Ohio and Pennsylvania. Approximately two-thirds of Cleveland's ore receipts are handled in the outer harbor for this purpose; the remaining one-third is delivered directly by the carriers to the furnaces on the river harbor (Plate IV, fig. 5).

As the vessels enter the harbor, they tie up to the wharf on which are mounted great unloaders operating on tracks. These machines invariably operate in batteries of 4 to 6 to enable them to unload simultaneously. During the unloading the ore is tested. As it is grabbed from the hold—10, 17, or 20 tons at a single bite—it is weighed and either carried to waiting railway cars under the machines, to be whisked away to inland points or dropped into stock piles at the rear (Plate IV, fig. 4).

Inland furnaces arrange their schedules so as to absorb a steady stream of this "direct ore," for by so doing, they save 25 cents over the equivalent "dock ore" rate.

Outer Harbor Characterized by Dearth of Furnaces.—In contrast with the situation in Chicago, where furnaces and mills nudge each other for space along the lake front, there is a total absence of such plants in Cleveland's outer harbor. This situation, which seems so anomalous, promptly arouses the geographer's curiosity and is found to be consequent upon the following conditions.

(1) The width from the harbor line to the high bank is too narrow to sustain an industry demanding such large tracts of land.
(2) The outer harbor is so well suited to the needs of commerce that the city rightfully wants it reserved for that purpose.
(3) For three-quarters of a century, the lower river was Cleveland's sole harbor, and industrial plants were established here to benefit from the only transportation available.
(4) The cost of this land is prohibitive to an industry needing *large* tracts of *cheap* land. Cleveland firms operating on such costly terrain could scarcely compete with more fortunate rivals, *e.g.*, Gary, Chicago and Buffalo.

The Inner Harbor.—The actual manufacture of iron and steel is confined to the river or industrial harbor. Here blast furnaces,

steel plants, and associated industries have acquired the entire valley bottom for two miles back from the lake, seeking the "major advantage derived from contact of lake and land traffic."[4]

Obstacles Presented by the Cuyahoga.—The Cuyahoga always has presented difficulties to navigation. These difficulties are now intensified; for as Cleveland has grown, so too have the lake steamers, and the river's defects have become aggravated until now the Cuyahoga is the biggest physical obstacle confronting the city and its many interests.

Formerly sand bars obstructed the entrance to the river. But these were overcome, first early in the nineteenth century, when the channel was constricted with jetties, and again in 1910–1911, when it was deepened by dredging. The latter operation enabled boats to navigate the river, for the first time, as far as the Cleveland Furnace Company, now owned by the Otis Steel Company (fig. 6).

The river's most glaring defect now is its tortuous course, which for many years has hindered the city's commercial and industrial development. Yet so long as relatively small boats utilized the stream and the lakes (true until 1900), no serious inconvenience was experienced by Cleveland. Progress, however, is predicated upon change, and change has characterized lake transportation; the boats have increased notably in size, because of the economies they afford. For instance, there is a saving of at least 6 cents per ton where ore is shipped in a vessel 600 feet long with a capacity of 12,000 tons rather than in one 400 feet long with a capacity of 6,000 tons, and to this should be added about 2 cents to cover the added cost of unloading the smaller boat.[5] As early as 1913 only 55 per cent of the lake carriers could navigate the abrupt bends and the narrow channel of the lower river, and by 1924 this had been reduced to 32 per cent. Moreover, the percentage decreases annually. Undoubtedly Cleveland lost the plant built by the Lorain Steel Company at Lorain, for this very reason; a Cleveland site was sought first.

[4] Strong, Helen M., *Op. cit.*, p. 199.

[5] Report of the Special Committee of the Cleveland Chamber Chamber of Commerce, July, 1913, p. 16.

At present only one of Cleveland's iron and steel manufacturers—the Bourne-Fuller Company—is served by the largest freighters (fig. 6).

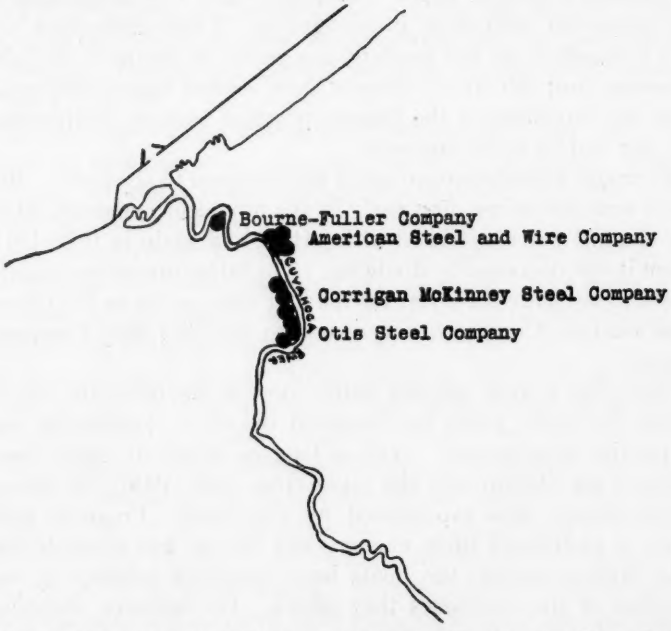


Fig. 6. Distribution of blast furnaces in Cleveland. Note that the furnaces are confined to the banks of the Cuyahoga, thereby enabling them to benefit from cheap water transportation rates on ore and limestone. Even the scale of this map enables one to understand how difficult it is for lake steamers to navigate the abrupt bends of the stream. The capacities of the several companies in 1926 were:

	Pig Iron (*tons*)	*Steel Ingots* (*tons*)
American Steel and Wire Company	770,000	970,000
Bourne-Fuller Company	130,000	240,000
Corrigan McKinney Steel Company	1,000,000	1,000,000
Otis Steel Company	400,000	421,000

The Possible Remedy.—Numerous capable committees have been appointed by the Cleveland Chamber of Commerce to work out a satisfactory river straightening project, yet nothing has come from their many excellent suggestions. Such a project

would prove highly advantageous to the city in general and the metallurgical industry in particular, for it would (1) offer unobstructed navigation to large local commercial and industrial interests, (2) reduce the increasing expenditures for dredging so sluggish a river now borne annually by the taxpayers, (3) mitigate the danger from floods, which have wrought much damage decadally since 1884, and (4) make available for heavy industries a tract of about 2,600 acres in the upper Cuyahoga Valley.

Something must be done; every annual delay augments both cost and difficulty, and according to a specialist on Cleveland factory sites, "sees large industries which Cleveland should have, locate along the shore of Lake Michigan."

Assembly of Raw Materials in the River Harbor.—Because of its favorable relation to raw materials, Cleveland enjoys remarkably low assembly costs—a potent competitive metallurgical advantage. Its favorable site guaranteed it a place in the iron industry, a place that has become more strategic as decentralization has occurred.

Since Buffalo and Chicago, as well as Cleveland, benefit from cheap water transportation on ore and flux, precisely where is the latter's assembly vantage point? *It lies in its greater proximity to coking fuel.* Whereas Chicago must pay $3.29 per net ton on all-rail delivered Pohontas, Cleveland pays but $2.64. Moreover, 85 per cent of Cleveland's blast furnace fuel comes from districts from which the freight rates range from $1.90 to $2.39 per net ton. Pocahontas is ordinarily mixed with these other coals in a relationship of from 15 to 85 to 20 to 80.

Almost all Cleveland's furnace fuel is converted into coke in iron and steel company by-product ovens. Only the Bourne-Fuller Company, which operates bee-hive ovens in the coal-mining region, gets fuel as coke.

A comparison of assembly costs in the three rival districts—Cleveland, Pittsburgh, and Youngstown is presented in table 1. In this study the weight of the raw materials required to produce one gross ton of pig iron is 4,000 pounds of ore, 2,050 pounds of coke, and 900 pounds of limestone.

CLEVELAND IN RELATION TO LEVEL LAND

Large areas of flat cheap land are indispensable to a metallurgical industry. If they are wanting, potential manufactures go elsewhere and the district's growth is arrested; but if they abound, industries and district alike grow, providing, of course, the other major factors are present and functioning.

The land well suited to iron and steel manufacture is limited indeed in Cleveland, and is confined to a narrow ribbon of flood plain along the Cuyahoga, 3,000 feet wide, 11.5 miles long (back from the lake) and 4,300 acres in extent. Near the river's mouth, the land is about 8 feet above normal stream level and at the upper end, 30 feet. The *entire area* is being utilized and throbs with industry.

However, a desirable and valuable tract of 2,600 acres in the upper valley awaits reclamation. It may be had by straightening the river; no grading is necessary to reduce its level and no locks need be constructed.

CLEVELAND'S INDUSTRIAL WATER SUPPLY

While industrial water never determines the general location of an iron industry, it frequently determines the specific site, and should be considered a genuine asset. Cleveland has two sources of water, *viz.*, the river and the lake.

The Cuyahoga—the Actual Source.—Nearly all the water used by the metallurgical industry is drawn from the river. It is estimated that the amount pumped from the Cuyahoga is twice that drawn from the lake by the city water department. Since the latter in 1927 pumped from the lake an average of 159,096,000 gallons per day, the estimated daily withdrawal from the river is 318,192,000 gallons.

Within the limits of navigation, the supply is unlimited in quantity, since it is being returned continuously by the users, and since the river and lake have the same elevation. But the channel above navigation cannot be relied upon by such large water users, for it is too small in cross-section and its gradient is too great to permit it to act as a reservoir.

What the lower river gains in *quantity*, it loses in *quality:* its water has become polluted and has attained high temperatures, the latter resulting from its continued utilization for cooling purposes. It is exceedingly doubtful whether it is fit for industrial use, and a new supply is being sought.

Possible New Sources of Water Supply.—While Lake Erie affords Cleveland steel interests an unexcelled reservoir of industrial water, it has been ignored by them thus far. Small quantities are purchased from the city at the high cost of 7.5 cents per thousand gallons for boiler purposes, the water in the lower river being ill adapted to such usage. Because the American Steel and Wire Company at Newburgh has no supply of raw water at hand, it has to buy its entire supply from the city. The Municipal Research Bureau of Cleveland, however, has proposed placing an intake a short distance in the lake for the purpose of supplying all the large consumers on the valley floor. It estimates that it can supply them with all the water they need at the rate of 1.25 cents per thousand gallons. The cost of pumping the present supply is 1 to 2 cents per thousand gallons.

Another alternative is the upper Cuyahoga; the river could be dammed below Dunham Road, thus forming a tremendous reservoir with a capacity of 3.5 billion cubic feet. If 2 billion feet were utilized for flood control, the remaining 1.5 billion feet would be available for industrial uses. This water could be supplied for 1.25 cents per thousand gallons without pressure. An added advantage of this proposal lies in the flood relief it affords.

CLEVELAND AND LABOR

While labor is an important factor, it plays but a minor rôle in the actual location of an iron and steel industry. Moreover, its cost amounts to less than 10 per cent of the cost of making iron as contrasted with the more than 80 per cent for raw materials.

Because of Cleveland's low living costs and because it lies along the chief route of travel from New York—the chief port of entry—to Chicago, capital of the Middle West, it draws many immigrants to it. Moreover, most of the work in this industry is performed

by foreigners; an investigation of the Cleveland Education Survey[9] disclosed the fact that more than 80 per cent of the total operating force in the metal trades was of foreign birth.[10] Poles, Czecho-Slovaks, and Jugo-Slavs predominate numerically. Americans, as executives and highly skilled workers, constitute a relatively small class, probably not in excess of 5 per cent. While the foreigners perform essentially the unskilled and semi-skilled tasks, many also perform skilled work.

The cost of labor here is about the same as in all lake districts, slightly less than in Pittsburgh, and considerably more than in the Birmingham and Eastern Districts.

CLEVELAND'S PROBABLE FUTURE

Cleveland's future metallurgically seems assured; its iron industry will grow, though not sensationally. The rapid expansion, which characterized many districts during the past several decades has been halted. Practically all experts are agreed that the country already has adequate metallurgical capacity. In fact production could easily exceed consumption. Few districts are operating at 100 per cent capacity; most of them average from 80 to 90 per cent. Eckel recently stated that "For the first time in 150 years, we are passing through decades in which the world iron industry, which for that long period had consistently expanded some 50 per cent each 10 years, is now merely holding its position."[11]

Moreover, the profits of steel-makers are meager as a result of overproduction and cut-throat competition. What Scoville Hamlin said of *all* industry certainly is applicable to the iron and steel branch: "The rate of expansion of the manufacturing industry is cutting into its margin of profit."[12]

[9] Lutz, R. R., "The Metal Trades," Cleveland Education Survey, Cleveland Foundation, 1916.

[10] In making a study of the nationalities in its employ, the American Steel and Wire Company found that 82 different languages were spoken in its plants.

[11] Eckel, E. C., "Iron Industry Facing Great Changes," *The Iron Age*, June 14, 1928, p. 1669.

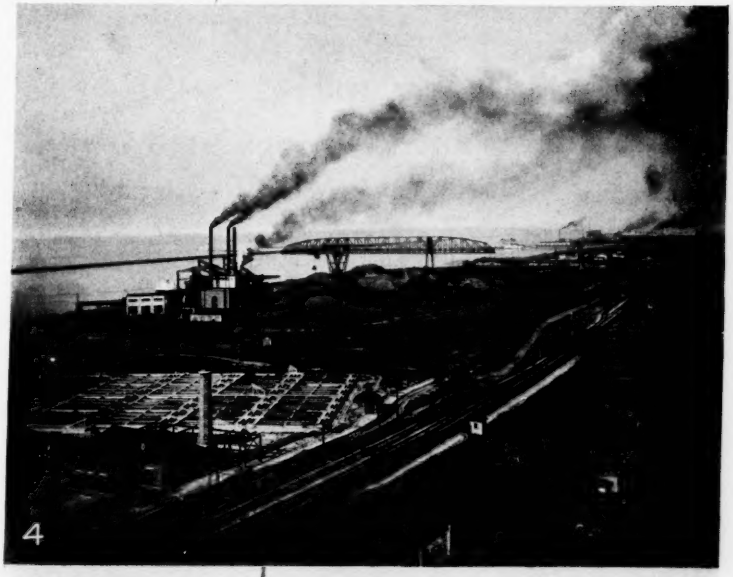
[12] Hamlin, Scoville, *Waste Not—Want Not*, Dorrance and Company, Inc., Philadelphia, 1928, p. 109.

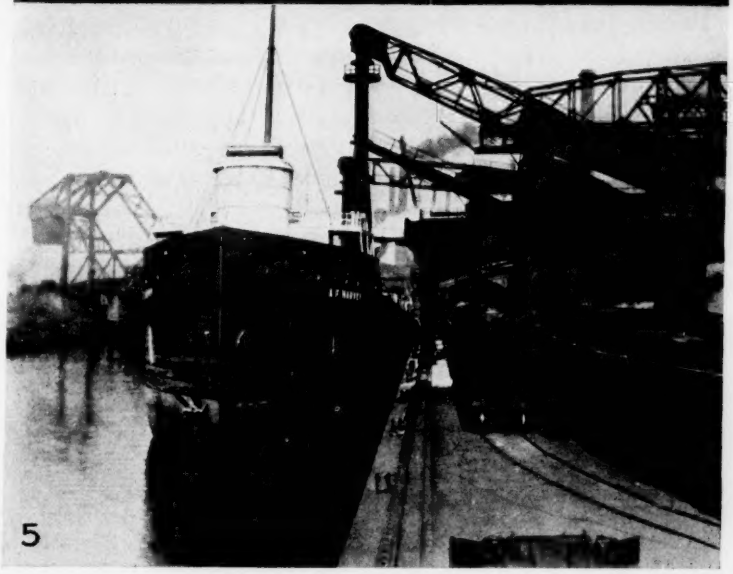
Yet with the lowest assembly and pig iron costs in the North, and with big markets both at home and in Detroit, Cleveland's future seems bright indeed. In order to advance, however, it must straighten the Cuyahoga so as to (1) enable the largest freighters to reach the mills with facility, (2) prevent floods, and (3) make new land available for the expansion of established industries and for the creation of new ones.

PLATE IV

Fig. 4. Unloading an ore boat in the west basin of the outer harbor. The breakwater, which protects the outer harbor, is clearly shown. The great piles of red ore behind the unloaders will be sent to inland iron and steel districts after the close of the navigation season. (Courtesy of Convention Board, The Cleveland Chamber of Commerce.)

Fig. 5. Unloading an ore boat in the Cuyahoga River. The photo shows remarkably well what a comparatively narrow ribbon of water the river actually is. (Courtesy of Convention Board, Cleveland Chamber of Commerce.)





CHARLES LANGDON WHITE IRON AND STEEL INDUSTRY OF CLEVELAND, OHIO

A PHOTOGRAPHIC RECORD OF THE TOTAL ECLIPSE OF THE MOON, NOVEMBER 27, 1928

PAUL BIEFELD

Received February 26, 1929; published April 24, 1929

The total eclipse of the moon was photographed at Swasey Observatory, Denison University, Granville, Ohio. With the exception of making the actual exposures, all the work during the eclipse was done by students in the regular courses in astronomy, and it affords the author great pleasure to acknowledge his indebtedness to them.

DESCRIPTION OF METHOD

An ordinary plate holder, 3.25″ x 4.25″, was fitted into a metal frame provided with a circular opening and external thread for joining it to the tube of the 9″ Equatorial which ordinarily takes the various eye-end attachments. The exact focus was obtained in the usual way, with full aperture, and exposure times were estimated according to the varying brightness of the moon. Cramer "Contrast" plates were employed, and 23 exposures were made. Data are given in table 1 and as legends to the photographs (Plate V).

The first photograph gives the angle of position from the North Point to East as 96° at first contact; the last photograph gives the angle of position from the North Point to West as 129° at the last contact.

Observatory Data

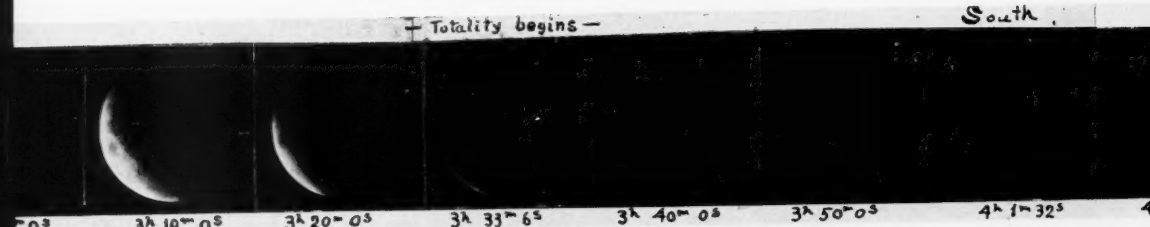
Latitude, 40°4′45″.5
Longitude West of Greenwich, 5 hr. 30 min. 4.5 sec.
Log. ρ (including altitude), 9.999424
Altitude (floor of transit room), 1094.33 ft.

TABLE 1

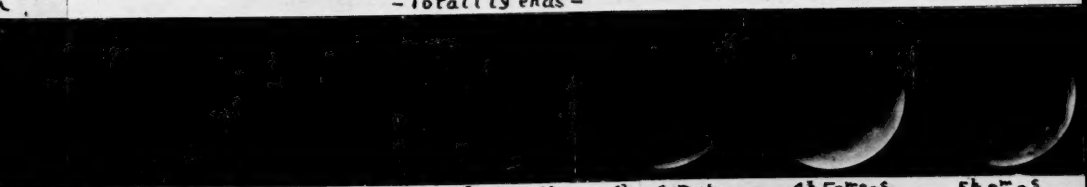
Data of the Eclipse

PHOTOGRAPH NUMBER	REMARKS	TIME (EASTERN STANDARD)			
		Day	*Hour*	*Min.*	*Sec.*
	Moon enters penumbra	27	1	25	24
1		27	2	20	00
2	Moon enters umbra	27	2	23	48
3		27	2	30	00
4		27	2	40	1
5		27	2	50	00
6		27	3	00	00
7		27	3	10	00
8		27	3	20	00
9	Totality begins	27	3	33	6
10		27	3	40	00
11		27	3	50	00
12		27	4	1	32
13		27	4	10	3
14		27	4	20	25
15	Totality ends	27	4	29	18
16		27	4	40	00
17		27	4	50	20
18		27	5	00	00
19		27	5	10	00
20		27	5	20	24
21		27	5	29	45
22	Moon leaves umbra	27	5	39	00
23	Last contact	27	5	50	00

PAUL BIEFELD

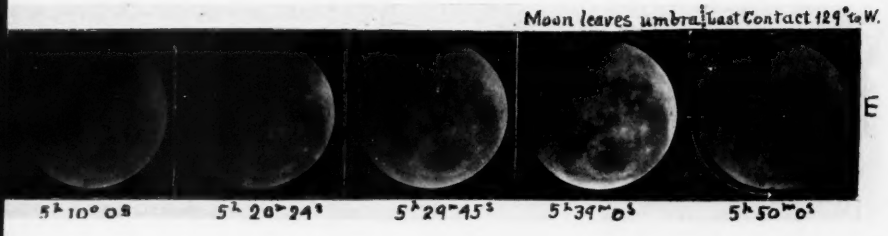

+ Totality begins —
South.
3h 10m 0s
3h 20m 0s
3h 33m 6s
3h 40m 0s
3h 50m 0s
4h 1m 32s

- Totality ends -



^{h}32^{s} 4^{h} 10^{m} 3^{s} 4^{h} 20^{m} 25^{s} 4^{h} 29^{m} 18^{s} 4^{h} 40^{m} 0^{s} 4^{h} 50^{m} 20^{s} 5^{h} 0^{m} 0^{s}

PLATE V



TOTAL ECLIPSE OF THE MOON

BASSLERINA, A NEW HOLLINIFORM OSTRACODE GENUS, WITH DESCRIPTION OF NEW PENNSYLVANIAN SPECIES FROM TEXAS AND OKLAHOMA

RAYMOND C. MOORE

Received March 7, 1929; published April 24, 1929

Among fossil ostracodes of Paleozoic age, the grooved shells of beyrichian aspect, now comprised in the superfamily Beyrichiacea, are probably altogether the most abundant, widely distributed and stratigraphically important representatives of the order; certainly they are the most interesting in point of varied surface and structural characters and in the evidence, which a more complex organization affords, of genetic relationships. Originally almost every grooved or nodose carapace was assigned to McCoy's genus, *Beyrichia*, established in 1846. Gradually the number of known species became very large and it became clear that the diverse types of shells that had been thus thrown together were susceptible of division into several more or less distinct minor groups. Due mainly to studies of Jones, Holl, Kirkby, Ulrich and Bassler the beyrichian ostracodes have now come to be divided into five major families that together include not less than sixty genera.[1]

Under the name *Hollina*, Ulrich and Bassler[2] in 1908 segregated a group of Devonian and Carboniferous species that previously had been referred to *Beyrichia*, *Ctenobolbina* and *Bollia* describing the new genus thus erected, as follows:

Genus *Hollina* Ulrich and Bassler

"Carapace elongate, produced and tapering somewhat anteriorly, essentially equivalved. Valves provided with a marginal frill, concave on the inner side,

[1] See Ulrich, E. O., and Bassler, R. S., Paleozoic ostracoda; their morphology, classification and occurrence, Md. Geol. Survey, Silurian, 271–324 (1923).

[2] Ulrich, E. O., and Bassler, R. S., New American Paleozoic Ostracoda, Preliminary revision of the Beyrichiidae, with descriptions of new genera. U. S. Nat. Mus., Proc., 35, 315 (1908).

overhanging the contact edge, often wanting at the anterior end. Except for two constant rounded nodes, the lobation of the surface varies greatly. One of the constant nodes is situated close to and partly in front of the middle of the hinge line; the other, usually the smaller, is placed lower and more or less behind the center of the valve. Occasionally, the hollow between these two nodes is excavated. In most species there is a continuous or broken ridge in the ventral part, in one (*H. kolmodini*) this ridge continues up the hinder end to the dorsal angle, in others (*H. insolens* and *H. tricollina*) the post-dorsal extremity remains prominent and forms a rounded node, the remainder of the ridge being dissected and tending to obsolescence; in two other species (*H. granifera* and *H. antespinosa*) the ventral ridge joins the two constant nodes, the result being a loop as in *Bollia*. Finally, in a later stage (as, for instance, *H. radiata*) the ventral ridge is obsolete and only two rounded nodes remain. Occasionally an extra node is developed near the anterior margin. A ventral pouch, as in *Beyrichia*, has not been observed.

"*Genotype. Hollina insolens* (*Ctenobolbina insolens* Ulrich)."

Including the genotype, eight Devonian species are assigned to *Hollina*. They are notably variable in the character of their nodation except that in each there is a large rounded node next the hinge line slightly in front of the mid-length of the valve, and another, generally smaller node slightly behind the mid-length. The first node, as pointed out by Ulrich and Bassler, is clearly homologous with the anterior node in *Beyrichia*, and the second represents the posterior beyrichian node. *H. insolens* is decidedly multituberculate, for in addition to the two nodes already mentioned there is one near the antero-dorsal angle, another near the postero-dorsal angle and two in the ventral region. Externally this species shows no indication of the presence of a frill, unless perhaps in the strongly marked notch that is made by the anterior termination of the frill; the surface of the valve in the ventral and posterior region is confluent with the outer curved slope of the frill, and the true structure appears clearly only in a view of the interior. *H. kolmodini* has a long curved node extending from the postero-dorsal angle almost around the two centrally located dorsal nodes, and in addition, a small elongate node at the antero-dorsal angle. As in *H. insolens*, the presence of a frill is not evident externally but is well shown in a view of the interior. Without further notice of these Devonian species, we may observe that if truly congeneric, they are distinguished by a high degree of instability in form, with a

marked tendency toward development of more nodes than the two dorsally central ones; also, the character of the frill may be, as in the genotype, quite unlike that of the Carboniferous species which we may now consider.

The first described of any of the species referred by Ulrich and Bassler to *Hollina* are two British Carboniferous forms, *H. radiata* (Jones & Kirkby) and *H. longispina* (Jones & Kirkby). Both of these species, originally assigned to *Beyrichia*, show the presence of two strong nodes near the middle of the dorsal half of the shell, but no additional tubercles; the former has a well developed frill that extends from the postero-dorsal angle to the antero-ventral region, while the latter lacks a frill, having instead two very prominent tubular spines that project outward and forward from the ventral border. In America, Ulrich and Bassler[3] have identified with *H. radiata* a species occurring in the "Cottonwood shales," basal Permian, of east central Kansas, and from the lower Permian Wreford horizon they have described the species *H. emaciata*. In addition, three species, *H. granifera* (Ulrich), *H. tricollina* (Ulrich) and *H. radiata cestriensis* Ulrich, have been described from American Mississippian beds,[4] and eight species, *H. grahamensis* Harlton, *H. radlerae* Harlton, *H. buehleri* Knight, *H. fortscottensis* Knight, *H. ulrichi* Knight, *H. bassleri* Knight, *H. granifera* (Ulrich) and *H. tricollina* (Ulrich), from Pennsylvanian beds.[5]

Of these species, all but *H. tricollina* and *H. radlerae* agree with Jones and Kirkby's *H. radiata* in having but two nodes, the anterior large and more or less bulbous, the posterior smaller and situated slightly lower than the anterior. *H. grahamensis* and

[3] Ulrich, E. O., and Bassler, R. S., New American Paleozoic Ostracoda, notes and descriptions of Upper Carboniferous genera and species, U. S. Nat. Mus., Proc., 30, 156, (1906).

[4] Ulrich, E. O., New and little known American Paleozoic Ostracoda, Cin. Soc. Nat. Hist., Jour., 13, 189, 204, 205, (1890).

[5] Harlton, B. H., Some Pennsylvanian Ostracoda from the Glenn and Hoxbar formations of southern Oklahoma and of the upper part of the Cisco formation of northern Texas, Jour. Pal., 1, 203–204, (1927); Harlton, B. H., Pennsylvanian Ostracods of Oklahoma and Texas, Jour. Pal., 2, 133 (1928); Knight, J. B., some Pennsylvania Ostracodes from the Henrietta formation of eastern Missouri, Jour. Pal., 2, 235–241 (1928).

H. bassleri lack the frill, and on this character mainly are assignable to Coryell's genus *Hollinella.*[6] The frill is a well developed feature of the shell in the other species, being more or less incurved in the posterior portion in *H. radiata, H. ulrichi* and *H. fortscottensis,* but erect and not distinctly incurved in the others. Excluding forms referable to *Hollinella,* it is apparent that Carboniferous species placed in *Hollina* are distinguished by the presence of a frill and in general by the occurrence of only two nodes. Unlike the Devonian species there is a marked stability in the nature of the nodation, and the frill does not overhang the valve margins so as to form practically or actually an inclosed space, nor does the frill lie in the plane of the valve surface so as to appear confluent with it. There is certainly reasonable doubt that the supposedly instable Devonian species and the relatively stable Carboniferous species now assembled under *Hollina* constitute a natural genetic group; indeed, Ulrich and Bassler indicate this in suggesting that certain different species of *Hollina* are probably derived from different antecedent genera. On the other hand, there is little doubt that the binodate frilled species are congeneric. Even though the Carboniferous forms are demonstrably a stock descended from a Devonian hollinid, it seems desirable to set them in a distinct category. Besides the adequate biologic basis for such emendation of classification, there will be advantage in definite and uniform treatment in designation of the nodes. Since the genotype of *Hollina* (*H. insolens*) is one of the multinodate forms we may restrict this genus to frilled ostracodes of the general type of *H. insolens,* that is, having besides the two dorsally central nodes one or more additional nodes. We propose to separate the binodate, frilled ostracodes in a new genus which, after Dr. R. S. Bassler, is named *Basslerina.* Under this classification, *Hollina* becomes essentially a Devonian assemblage with a few Carboniferous species; *Basslerina,* as now known, is made up of species from Mississippian, Pennsylvanian and Permian strata.

[6] Coryell, H. N., Some new Pennsylvanian Ostracods, Jour. Pal., 2, 377–381 (1928).

Genus *Basslerina* Moore, new genus

Carapace subelliptical in outline, valves essentially equal, gently to moderately convex, the dorsal region, excepting the nodes, somewhat more compressed generally than the ventral; hinge-line straight, postero-dorsal angle obtuse, antero-dorsal obtuse to acute. Medially in the dorsal half of each valve are two nodes; the larger more or less strongly bulbous, situated just in front of the mid-length of the valve, its dorsal edge, as seen in side view, commonly even with or projecting somewhat above the hinge-line; the smaller more or less strongly protuberant, situated just behind the mid-length of the valve, its ventral edge commonly even with or slightly lower than the ventral edge of the anterior node. Median sulcus between the nodes depressed or not depressed below the general valve surface dorsally, terminated ventrally by the even or ridge-like swelling of the median ventral portion of the valve. A submarginal frill rising at a distinct angle to the valve surface, standing straightly erect or in part more or less curved inward or outward with respect to the valve margins, extends from the antero-ventral region to or near the postero-dorsal angle. Surface smooth, granulose or spinulose.

Genotype.—Basslerina limata Moore n. sp.

Among described species, the following appear referable to *Basslerina: B. radiata* (Jones & Kirkby), *B. radiata cestriensis* (Ulrich), *B. ulrichi* Knight, *B. buehleri* Knight, *B. fortscottensis* (Knight), *B. emaciata* (Ulrich and Bassler), and *B. granifera* (Ulrich). Carboniferous species of *Hollina* as restricted may include: *H. tricollina* (Ulrich), *H. radlerae* Harlton, and the new species here described, *H. obsita* Moore. To *Hollinella* are referred: *H. dentata* Coryell, *H. ovata* Coryella, *H. regularis* Coryell, *H. grahamensis* (Harlton), *H. bassleri* (Knight), *H. oklahomaensis* (Harlton) and *H. ? longispina* (Jones & Kirkby).

Because of the specialization of various characters in the carapace of the holliniform ostracodes and the comparative readiness with which minor differences may be distinguished, these shells appear to have much more value for stratigraphic work than

some of the smooth, unfrilled genera. Close study of specimens from different horizons generally reveals slight but constant difference in certain characters, and discrimination of these dissimilarities is requisite for purposes of accurate correlation of the Pennsylvanian faunas. Some types, such as *B. radiata*, are apparently long ranging and very widely distributed, for there is very little difference between the British species, in so far as determinable from figures, and American specimens obtained from horizons ranging from upper Mississippian to Permian, yet comparison of *B. ulrichi* and *B. fortscottensis* from the lower Pennsylvanian of Missouri, *B. recurva* from the upper Pennsylvanian of north Texas, and the forms identified by Ulrich and Bassler, as *B. radiata* from the lower Permian of Kansas, all of which are of the *B. radiata* (J. & K.) type, appears to show distinguishable differences. In this connection it may be pointed out that most published illustrations are deficient in that only the side view of the carapace is generally given. Often, as indicated in the figures accompanying this paper, the aspect of a shell in ventral, dorsal, anterior or posterior view may be decidedly helpful. It is, of course, necessary to orient the specimens carefully for comparative study of incorrectly oriented shells might be very misleading.

DESCRIPTION OF NEW SPECIES

Family BEYRICHIIDAE Jones (emend. Ulrich and Bassler)

Genus *Hollina* Ulrich and Bassler

Hollina obsita Moore, n. sp.

Pl. VI, fig. 4; Pl. VII, figs. 9, 10; Pl. VIII, figs. 11, 12

Valves subelliptical, slightly oblique, anterior more sharply rounded than posterior; hinge line straight but in side view the anterior and posterior nodes project slightly above the hinge line; ventral margin gently and regularly rounded, both antero-dorsal and postero-dorsal angles distinctly obtuse and slightly rounded. The valves are rather strongly convex, the thickness through the carapace nearly equalling the height; in end view the shell has

a subquadrate outline. Anterior node well developed, bulbous, slightly elliptical in shape, about 0.22 mm. in diameter; median sulcus broad, but distinctly depressed below general surface of the valve; median node small, rounded, distinctly elevated, situated about one-fourth of the height of the valves below the dorsal margin and obliquely anterior and below the posterior node which is placed near the postero-dorsal angle. The posterior portion of the valves, obliquely below the posterior node is slightly swollen, forming an obscure node that may be regarded as a continuation of the posterior node, for the saddle between is very shallow. A more or less distinct row of small nodes or spines occurs near the border of the valve except in the ventral area where they become obsolete, in the antero-dorsal area the rows diverge slightly from the valve margin, dying out near the anterior end of the frill and in the postero-dorsal area they converge to the valve margins slightly below the posterior end of the frill. A very closely spaced, even row of minute spinelets occurs next the valve margins except along the dorsum. A rather stout flange or frill extends from the postero-dorsal angle, where it is barely perceptible, to the antero-ventral portion of the valve where with full width, it abruptly terminates. The frill of the left valve is slightly more elevated than that of the right in the only specimen showing a left valve. Ventrally there is a faint line extending from the anterior edge of the frill obliquely posterior toward the valve margins; it becomes obsolete in the postero-ventral area. Surface very finely papillose. Measurements of the holotype, a complete specimen are as follows: length 1.15 mm., height, 0.64 mm., thickness through anterior nodes, 0.6 mm.; median node 0.44 mm. behind anterior. Two right valves, paratypes, show nearly identical measurements.

This species appears most closely to resemble *H. tricollina* Ulrich from the Hamilton (Devonian) of New York. In the Devonian species the median and posterior nodes are apparently more bulbous and the median sulcus is distinctly narrower; the marginal frill is wider and less extended anteriorally. The form from the lower Glenn (Pennsylvanian) of southern Oklahoma

identified as *H. tricollina* by Harlton[7] is doubtfully conspecific with the Devonian shells. According to Harlton's figures, his species differs from ours most strikingly in its laterally compressed, emaciated form, shown in dorsal view. There is no indication of the minor swelling below and behind the posterior node which is present in our specimens.

Horizon.—Top of Francis formation, Pennsylvanian.

Locality.—Near north line of sec. 8, T. 4N., R. 6W., near Ada, Oklahoma. No. 128–7.

Genus *Basslerina* Moore, n. gen.

Basslerina limata Moore, n. sp.

Pl. VI, fig. 1; Pl. VII, figs. 3, 4; Pl. VIII, figs. 5, 6

Carapace elongate, subelliptical, the anterior and posterior ends narrowly rounded, hinge line straight, ventral margin gently convex. Cardinal angles obtuse and somewhat rounded, obliquity of outline of the valves slight, being marked mainly by the frill. The convexity of the valves is rather small, the thickness of the carapace being only slightly more than half the height. The front edge of each valve, which is rather blunt bears an irregular row of spines, an unusually prominent spine occurring in some specimens at the antero-dorsal angle; along the margins is an even row of very close spaced tiny spinelets. Anterior node a low rounded swelling about 0.26 mm. in diameter, projecting slightly above the hinge line. Median sulcus of moderate width and distinctness, not impressed dorsally but well defined laterally by the nodes and ventrally by the higher, even contour of the valve in this region. Posterior node small, opposite the ventral margin of the anterior node, distinctly elevated. Frill of moderate width and strength, erect, extending from near postero-dorsal angle, where it is very narrow, to the antero-ventral region, where it is abruptly terminated. Surface covered by small, rather evenly spaced spinelets.

Measurements of the holotype are: length, 1.10 mm., height, 0.60 mm., greatest thickness 0.46 mm.

[7] Harlton, B. H., Jour. Pal., 1, 204 (1927).

B. limata resembles *B. buehleri* (Knight) in general appearance but comparison of the cotypes of the two species shows readily discernible differences. Knight's species is proportionately more elongate, the postero-dorsal angle more obtuse and the postero-ventral portion less produced than in our shells. The frill of *B. buehleri* extends anteriorally to a point directly below the antero-dorsal angle and along the posterior margin it is strong, though narrow, to the cardinal angle, curving away from the valve margin at about the mid-height of the valve; in *B. limata* the front end of the frill only reaches a point somewhat farther forward than the anterior nodes, and the posterior portion is both weak and not clearly extended to the dorsal angle. The posterior node in *B. buehleri* is moderately large and confluent posteriorally with the general valve surface but in our specimens it is smaller and elevated on the posterior side as well as on the others; the surface granulose markings of *B. limata* are slightly coarser.

Horizon.—Near top of South Bend shale member of the Graham formation, Cisco group, Pennsylvanian.

Locality.—On west bank of Salt Creek, north of highway, one mile west of Graham, Texas. No. 144–8.

Basslerina verrucula Moore, n. sp.

Pl. VI, fig. 6; Pl. VII, figs. 5, 6; Pl. VIII, figs. 3, 4

Carapace obliquely reniform, the postero-ventral area distinctly projecting so that despite obtuseness of the anterior as well as the posterior cardinal angle there is a marked backward swing in outline. Anterior node subhemispheric and bulbous, its dorsal edge approximately even with the hinge line in side view. Median sulcus faint toward the hinge line, a distinct, narrow depression between the nodes, becoming broad and dying out ventrally just beyond the nodes. Posterior node small, opposite the ventral edge of the anterior node, well defined only on the side toward the sulcus. Valves are rather strongly and evenly inflated. Frill thin, erect, bearing distinct radial markings, extends from a point slightly anterior to the mid-length of the venter nearly to the postero-dorsal angle; its anterior end which appears to be

unbroken curves backward; in the dorsal half of the posterior part of the frill there is a decrease in height to a barely perceptible line. The anterior and part of the ventral edges of the carapace are marked by a row of small spines on each valve, and along the margins is a very close-set even row of much smaller spinelets. Surface finely spinose, the spinelets being on the average about 20 microns apart.

Measurements of the holotype are: length 1.0 mm., height, 0.57 mm., thickness through anterior nodes, 0.45 mm., diameter anterior node, 0.25 mm.

In the marked retral trend of the shell outline, defined by the posterior margin and short forward extension of the frill, this species suggests shells of the *B. radiata* type. The very different nature of the frill and the generally more prominent posterior node clearly distinguish the latter group.

Horizon.—Top of South Bend shale member of the Graham formation, Cisco group, Pennsylvanian.

Locality.—On west side of Salt Creek, north of highway, one mile west of Graham, Texas. No. 144–10.

Basslerina regularis Moore, n. sp.
Pl. VI, fig. 3; Pl. VIII, figs. 7, 8, 15

Carapace elongate, semiovate, hinge line straight, obliquity hardly perceptible. The anterior margin meets the hinge line nearly at right angles, ventral border somewhat flatly rounded, posterior strongly and regularly curved, the postero-dorsal angle being distinctly obtuse and rounded. Anterior node subelliptical, large, in the holotype measuring 0.33 mm. in longer diameter, moderately elevated. Median sulcus distinct and rather deeply excavated, confined to the dorsal half of the valve and terminating ventrally at the swelling that extends longitudinally just below the median line of the shell. Posterior node well defined on the side toward the sulcus and by shallow depressions joined to the sulcus obliquely above and below the node, but on the posterior side it merges evenly with the general surface of the valve. Marginal frill or flange moderately stout, not strongly elevated, originating as a very low ridge at the postero-dorsal

angle where it curves rather sharply away from the valve margins for a short distance then follows sub-parallel to the margins to the antero-ventral area, where it is abruptly terminated. The frill meets the valve surface nearly at right angles and in side view there is a prominent, broadly rounded groove just above the frill. In anterior or posterior view the carapace is subrectangular, the thickness being approximately two-thirds of the height. Surface very finely papillose. An even row of minute spinelets occurs at the valve margins except dorsally. Measurements of the holotype are: length 1.35 mm., height 0.73 mm., thickness 0.44 mm. The species is characterized by its elongate form, slight obliquity, gentle convexity of surface and the nature of the frill.

B. regularis suggests *H. buehleri* Knight more closely than other described species. Knight's types show a distinctly more elongated character and more sharply rounded anterior margins and differences in the frill. From the associated *B. limata* this species is distinguished by its considerably larger size, more elongate form, and the thickened, less elevated frill which is clearly defined to the postero-dorsal angle.

Horizon.—Top of South Bend shale member of the Graham formation, Cisco group, Pennsylvanian.

Locality.—On west side Salt Creek, north of highway, one mile west of Graham, Texas. Moore Coll. 144–10.

Basslerina pulchra Moore, n. sp.

Pl. VI, fig. 5; Pl. VII, figs. 1, 2; Pl. VIII, figs. 1, 2

This species, somewhat below the average size, has a moderately short, semi-ovate carapace, with obliquity extremely slight. The thickness nearly equals the height, so that including the frills the end view is subquadrate. Both dorsal angles of the valves obtuse. The anterior node is sub-hemispheric, about 0.2 mm. in diameter, prominent and bulbous, but it does not project above the hinge line. The posterior node is about one-third as large and slightly protuberant; it is lower in position than the anterior node and located just behind the mid-length of the valve. The median sulcus is narrow and distinct, not impressed below

the valve surface in the dorsal area, but clearly defined between the nodes; it terminates ventrally by swelling of the sub-median portion of the carapace. As well shown in end view, the valve surface slopes moderately in the dorsal region, is most protuberant submedially and is most steeply inclined to the valve margins ventrally. A wide but thin frill, bearing more or less distinct radiate markings, is disposed approximately at right angles to the valve surface, and extends from the antero-ventral region where it is widest to the posterior portion where it is narrow and somewhat abruptly terminated or continued as a barely perceptible line to the postero-dorsal angle. The base of the frill maintains about the same distance from the valve margin, but it is slightly closer posteriorly than anteriorly. Surface very finely papillose. Measurements of the holotype are: length, 0.73 mm., height, 0.53 mm., thickness through anterior nodes, 0.4 mm.

B. pulchra is distinguished from described species by its small size, subquadrate outline, and moderately wide, thin, erect frill.

Horizon.—Near top of South Bend shale member of the Graham formation, Cisco group, Pennsylvanian.

Locality.—On west side of Salt Creek, north of highway, one mile west of Graham, Texas. No. 144–7.

Basslerina limbata Moore, n. sp.

Pl. VI, fig. 7; Pl. VII, figs. 11, 12; Pl. VIII, figs. 13, 14

Carapace semiovate, including frill the height is nearly equal to the length, the obliquity is slight but distinct, the anterior-dorsal angle being nearly ninety degrees and the posterior angle strongly obtuse, thickness moderate. In the anterodorsal region the surface of the valve is laterally compressed, sloping rather gently to the ventral bulge; the postero-dorsal area is slightly more inflated. The anterior node is subhemispherical, well differentiated from the valves and rather strongly protuberant. Posterior node one-third to one-half as large as the anterior and not so strongly elevated, but distinctly elevated on all sides. Median sulcus narrow, not impressed dorsally, very strongly defined between the nodes, expanding ventrally and terminated by a ridge-like swelling that extends longitudinally in a curve below

the nodes. This swelling broadens anteriorally and merges evenly with the antero-dorsal surface of the valve; beneath the posterior node it is sharply defined but not joined to the node. The frill in this species is unusually extended, standing erect or curving slightly outward away from the valve margins; it is widest in the mid-ventral region, decreasing in height along the posterior margin and extending to the postero-dorsal angle. A row of nodes, large and prominent in the anterior region but rather small in the posterior area, occurs near the valve margins. The entire surface of the valve is covered by minute spinules. Measurements of the holotype, a right valve, are: length, 1.18 mm., height, 0.80 mm., thickness (from outer edge of anterior node to plane of valve margin) 0.37 mm.

B. limbata is characterized by the protuberant nodes, ridge-like ventral bulge below the nodes and the very wide, slightly outwardly curving frill. It is distinguished from shells of the *B. radiata* type which likewise may have very prominent, globose nodes, by lesser obliquity and by the character of the frill which is not incurved and which is well defined to the postero-dorsal angle.

Horizon.—Wewoka formation, Pennsylvanian.

Locality.—One quarter mile north of southwest corner of Sec. 4, T. 3N., R. 7E., Oklahoma. No. 135–13.

Basslerina recurva Moore, n. sp.

Pl. VI, fig. 2; Pl. VII, figs. 7, 8; Pl. VIII, figs. 9, 10

Carapace with straight hinge line, rather marked obliquity due mainly to the strong development of the frill in the postero-ventral region and along the venter. The anterior border meets the hinge line at nearly right angles, often with a more or less prominent spine at the angle; the postero-dorsal angle distinctly obtuse and somewhat rounded. Anterior node subhemispherical, strongly bulbous, but not projecting above the hinge line, elevation above the general surface of the valve equal to one-half the diameter of the node. Posterior node rounded, protuberant, a little over one-third as large as the anterior node, its lower margin even with the lower margin of the anterior node. The pos-

terior postion of the valve slopes smoothly to the dorsal and posterior margins. Median sulcus rather narrow and distinct because of the prominence of the nodes on each side, but in the dorsal region it is not impressed below the level of the general valve surface; ventrally the sulcus is terminated by a longitudinal ridge-like inflation of the sub-median portion of the valve. The frill, bearing a few obscure radial markings, extends from the mid height of the valves at the posterior margin to the antero-ventral region; along the line of union with the valve the plane of the frill is nearly at right angles to the valve surface, but marginally it curves abruptly in toward the valve margin, the curvature being most pronounced posteriorly. The anterior part of the frill flares somewhat and may be produced in a fairly robust spine. At its posterior extremity the frill is broad, rounded, but little elevated from the valve, the frills of the two valves meeting in a rather broad, flat area above which is a slightly curved or angulated faintly marked ridge extending to the posterodorsal angle. The appearance of this ostracode in rear view somewhat suggests the head of a walrus. A row of spines occurs in the anterodorsal area near the margins. Surface finely spinose.

Measurements of a cotype are: length, 1.1 mm., height, 0.7 mm., thickness through anterior nodes 0.56 mm. Other specimens have practically identical measurements.

The general form of the shell here described is clearly similar to that figured by Ulrich and Bassler under the name *Beyrichia?* (=*Basslerina*) *radiata* Jones and Kirkby from the lower Permian "Cottonwood shales" east of Cottonwood Falls, Kansas. According to the figure, the frill of the Cottonwood specimen extends farther forward and the surface is covered with much coarser, more scattered spines than in our forms. The appearance in views other than from the side is not indicated. The inward curvature of the frill, most pronounced in the posterior region, is interpreted by these authors as an ephebic or gerontic character, and therefore variable in different specimens assignable to the same species. In our observation, on the other hand, there is considerable constancy in the nature of the frill and of other characters among forms from this as well as other horizons,

that, according to these features, may be divided into groups that do not intergrade. These distinct groups appear to represent specific or varietal differences rather than ontogenetic stages in a single species.

B. recurva resembles *B. fortscottensis* (Knight) in its somewhat prominent recurved frill, but that species is notably more elongate and the frill extends farther posteriorly and anteriorly. The posterior node is not so prominently elevated and the valve surface below the median sulcus is more distinctly elevated. Posterior and anterior views, as determined from the type, are quite distinct.

The specimens from the Henrietta formation of eastern Missouri designated *Hollina* (*Basslerina*) *ulrichi* by Knight, are clearly distinct from our species, and it is doubtful if they are the same as those described by Ulrich and Bassler from the lower Permian.

Horizon and locality.—The type was collected in the Wayland shale, at the locality, five miles west of Eastland, Texas, from which a large bryozoan fauna, elsewhere described by the writer, was obtained. Specimens identified with this species have been collected also from the Finis shale, (3 miles south of Jacksboro, Texas), South Bend shale (1 mile west of Graham, Texas), Boggy shale (Sec. 18, T. 3N., R. 7E., Oklahoma), and Hoxbar formation (0.7 mile S. of S. E. cor. Sec. 1, T. 5S., R. 2E., Oklahoma).

PLATE VI

Fig. 1. *Basslerina limata* Moore, n. sp., side view of a right valve, cotype, × 50.

Fig. 2. *Basslerina recurva* Moore, n. sp., side view of a right valve, cotype, × 50.

Fig. 3. *Basslerina regularis* Moore, n. sp., side view of a right valve, holotype, × 50.

Fig. 4. *Hollina obsita* Moore, n. sp., side view of a right valve, cotype, × 50.

Fig. 5. *Basslerina pulchra* Moore, n. sp., side view of a left valve, holotype, × 50.

Fig. 6. *Basslerina verruculla* Moore, n. sp., side view of a right valve, holotype, × 50.

Fig. 7. *Basslerina limbata* Moore, n. sp., side view of a right valve, holotype, × 50.

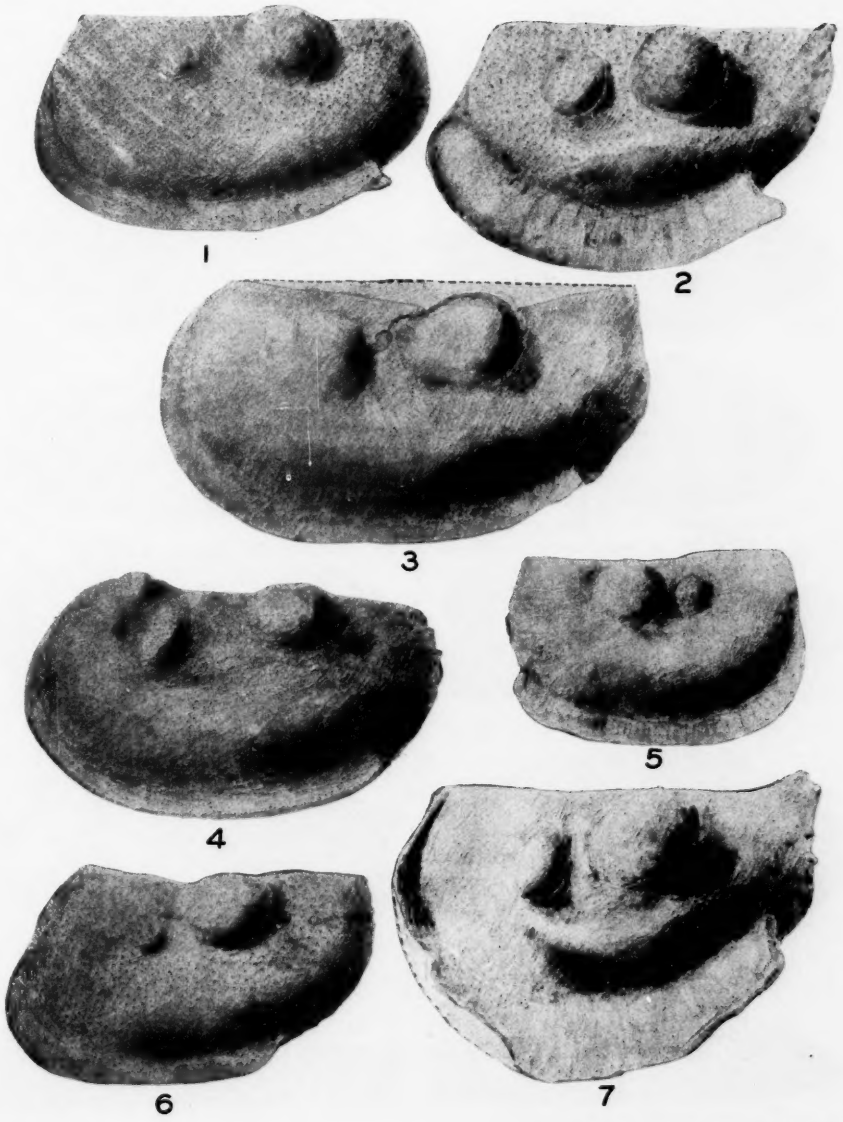

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PLATE VII

Figs. 1, 2. *Basslerina pulchra* Moore, n. sp. 1, dorsal view of the holotype, × 50; 2, ventral view of same, × 50.

Figs. 3, 4. *Basslerina limata* Moore, n. sp. 3, dorsal view of a cotype, × 50; 4, ventral view of same, × 50.

Figs. 5, 6. *Basslerina verrucula* Moore, n. sp. 5, dorsal view of the holotype, × 50; 6, ventral view of same, × 50.

Figs. 7, 8. *Basslerina recurva* Moore, n. sp. 7, dorsal view of a cotype, × 50; 8, ventral view of same, × 50.

Figs. 9, 10. *Hollina obsita* Moore, n. sp. 9, dorsal view of a cotype, × 50; 10, ventral view of same, × 50.

Figs. 11, 12. *Basslerina limbata* Moore, n. sp. 11, dorsal view of a right valve, holotype, × 50; 12, ventral view of same, × 50.

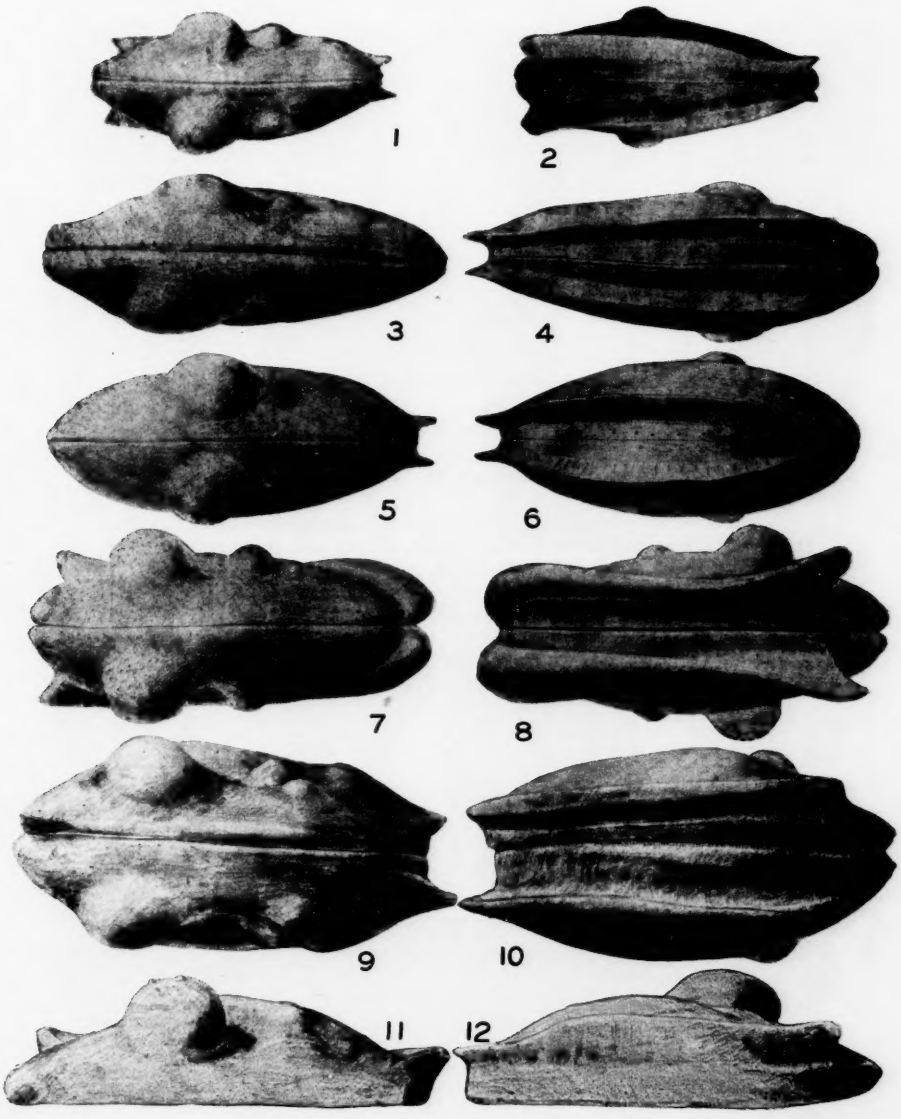
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PLATE VIII

Figs. 1, 2. *Basslerina pulchra* Moore, n. sp. 1, anterior view of the holotype, × 50; 2, posterior view of same, × 50.

Figs. 3, 4. *Basslerina verrucula* Moore, n. sp. 3, anterior view of the holotype, × 50; 4, posterior view of same, × 50.

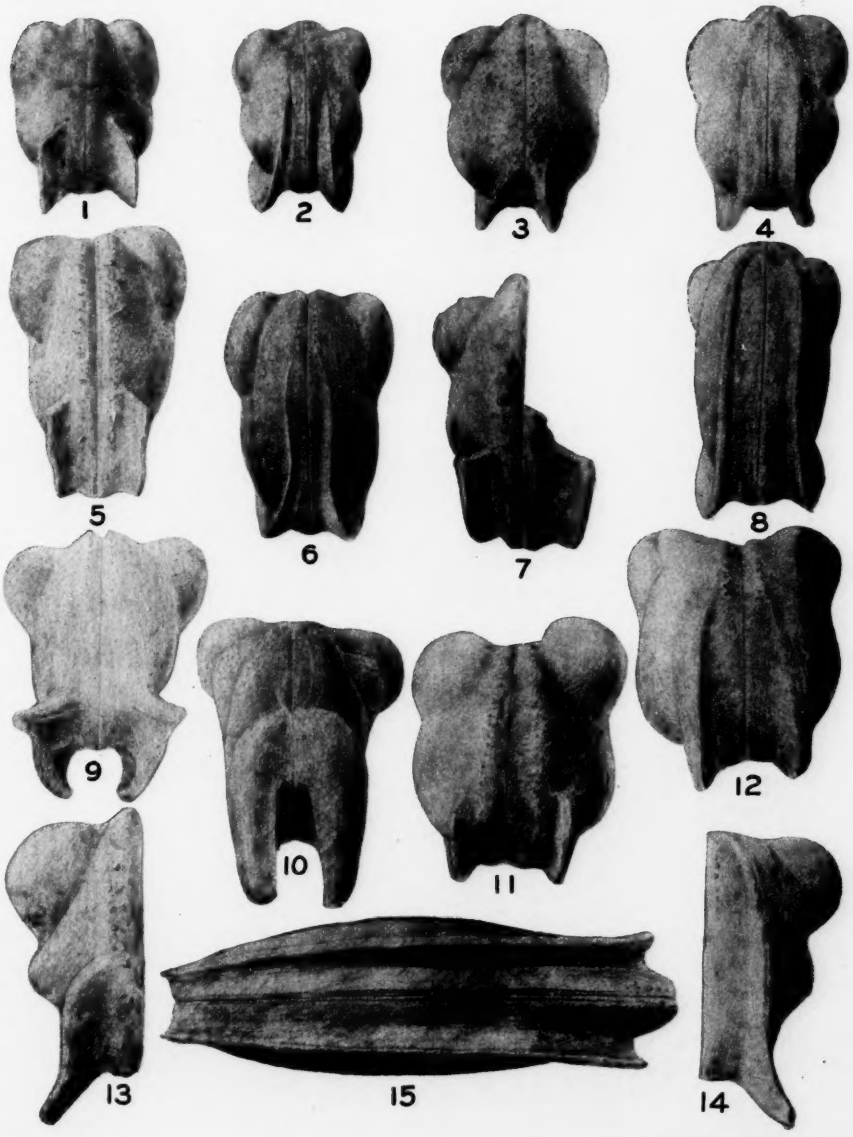
Figs. 5, 6. *Basslerina limata* Moore, n. sp. 5, anterior view of a cotype, × 50; 6, posterior view of the same, × 50.

Figs. 7, 8, 15. *Basslerina regularis* Moore, n. sp. 7, anterior view of the holotype, × 50; 8, posterior view of same, × 50; 15, ventral view of same, × 50.

Figs. 9, 10. *Basserlina recurva* Moore, n. sp. 9, anterior view of a cotype, × 50; 10, posterior view of same, × 50.

Figs. 11, 12. *Hollina obsita* Moore, n. sp. 11, anterior view of a cotype, × 50; 12, posterior view of same, × 50.

Figs. 13, 14. *Basslerina limbata* Moore, n. sp. 13, anterior view of a right valve, holotype, × 50; 14, posterior view of same, × 50.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